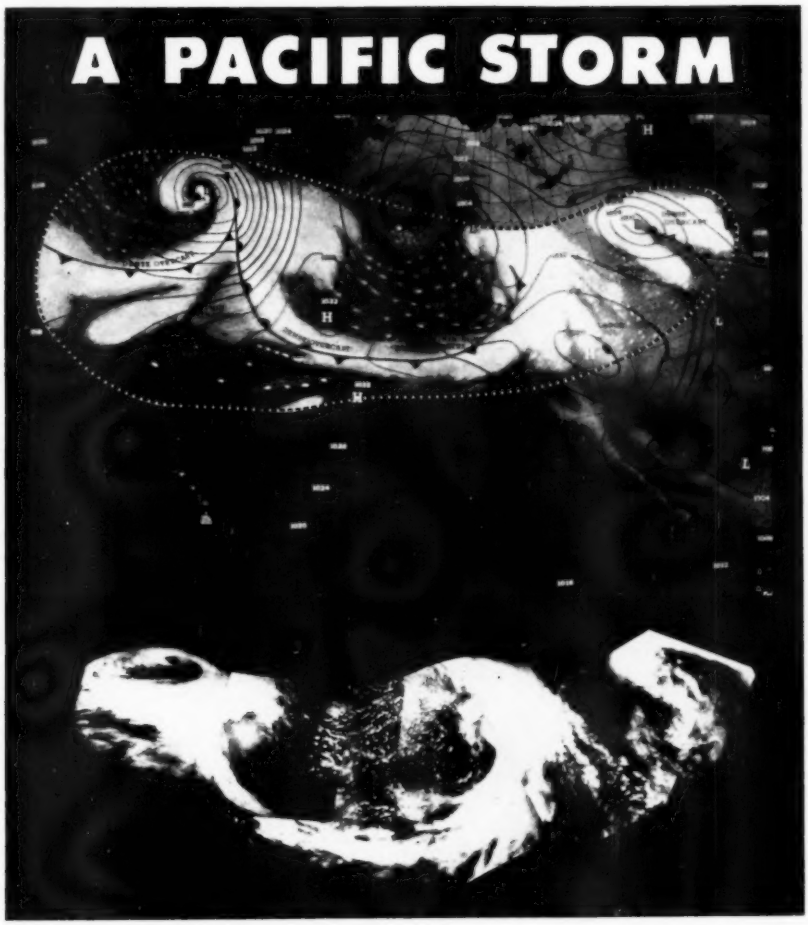
Weatherwise



TIROS CLOUD PICTURES

Volume 13, Number 5 October 1960

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Tiros Pictures a Pacific Frontal Storm

V. J. OLIVER, *U. S. Weather Bureau, Washington, D. C.*

METEOROLOGISTS for many years have known the general nature of storms but have lacked a measure of their individuality, a "cloud print" of the storm to identify it uniquely. Pictures taken by Tiros I now make excitingly clear the details of cloud patterns as well as the general structure of storms.

On 19–20 May 1960 several of the orbits of the weather satellite, Tiros I, crossed the North Pacific Ocean, the United States, and Central America. Pictures received during these orbits, show with unusual clarity a series of frontal storms which extended from north of Japan eastward across the Pacific to the east portion of the United States.

The cloud pattern as revealed by photographs taken on two of these orbits is presented on the front page of this issue. The upper portion shows the surface weather map for the eastern Pacific Ocean and western North America. The white area superimposed on the weather map is a schematic representation of the clouds seen in their original detail in the photographic mosaic below. The thick layers of storm clouds extend from the storm in the western portion of the picture eastward along the frontal system to another storm center along the west coast of the United States and Canada. Parts of a third dense band of frontal storm clouds can be seen on the eastern edge of the picture. Between the three storm centers the cloud patterns show the distinctive rows of cumulus clouds and clear areas which accompany cold unstable air and indicate alternating areas of showers and sunshine.

Although the larger-scale cloud patterns of most storms are similar, each has its own distinctive pattern, clearly identifying it from all others. Here at last is our long sought "cloud print" of the storm.

Further details of this composite illustration and the storm system will appear in a forthcoming publication of the National Aeronautics and Space Administration.

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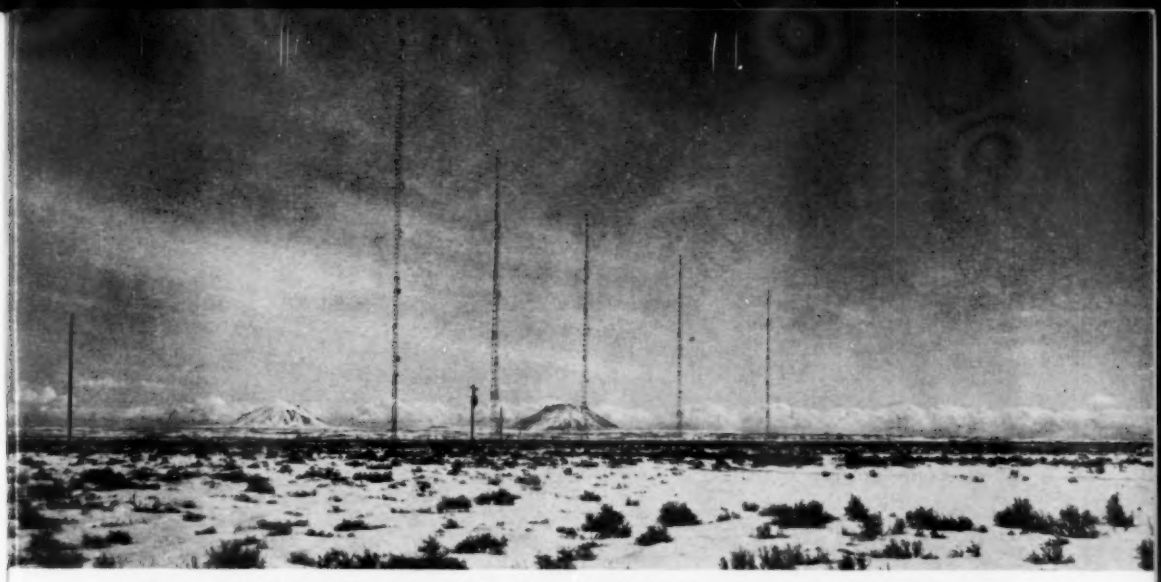


FIG. 1. The five 100-foot meteorological towers at the National Reactor Testing Station against a wintry Idaho background.

Weather Bureau Operations and Research at the National Reactor Testing Station[1]

GEORGE R. YANSKEY, *U. S. Weather Bureau, Idaho Falls, Idaho*

IN helping to realize the objective of completely safe operation of nuclear reactors and related facilities, the U. S. Weather Bureau has established offices at a number of Atomic Energy Commission laboratories and stations. Working closely with the Health and Safety Divisions of the AEC, these offices are engaged in unique operational and research programs.

One of the more interesting of the Weather Bureau's programs is located at the National Reactor Testing Station (NRTS), situated in southeastern Idaho fifty miles west of Idaho Falls. Reactor areas and construction sites are located throughout the 894 square miles within the site boundaries, and detailed weather forecasts are issued for every location. However, it is not the spaciousness of the local forecast area that makes the station singular. Operations such as nuclear fuel processing, testing of materials, and certain reactor experiments may result in the release of a radioactive effluent. Safety considerations as well as the need for environmental monitoring data, which may contribute significantly to experiments, require exact operational and diffusion weather forecasts and research studies to improve these forecasts. Some of the problems involved in the operational program are indicated in the following discussions of the topography, climatology, and meso-meteorology of the testing station.

The meteorological research program at the NRTS, although primarily directed at improving diffusion forecasts, has also included investigations of problems of concern to designers and engineers. A complete account of all the current research projects would necessitate a voluminous report. In this article, only the highlights of the work are discussed.

THE AREA

The terrain of the NRTS is predominately flat and uniformly covered with sagebrush. The average elevation is 5,000 feet above mean sea level except for the two buttes of

[1] The work described in this report is supported under contract to the Reactor Development Division, U. S. Atomic Energy Commission.

volcanic origin in the southeast corner which rise 1,400 and 1,600 feet and Big Southern Butte, just south of the station boundary, which rises 2,700 feet above the surrounding plain.

The mountains seen in figure 2 almost encircle the Snake River Plain and rise as much as 10,000 to 11,000 feet above mean sea level. Not shown in the figure are mountains to the west which complete the encirclement of the plain. While the Centennial Mountains form an unbroken barrier at the northern end of the Snake River Plain, the ranges to the northwest and southeast, which form the sides of the plain, are penetrated by deep valleys oriented northwest-southeast.

GENERAL CLIMATOLOGY

The topographic features in the preceeding description all greatly affect the climate of the NRTS (1; 2). The surrounding mountains dry out and channel air moving into the valley. Due to this drying the moisture content of the air is usually low, with most of the 7.5 inches of annual precipitation occurring as showers in the spring and summer. Snow accounts for 30% of the precipitation with depths averaging 3 to 4 inches during the winter.

Low air density associated with the elevation of the NRTS, relative dryness of the air, and infrequency of low cloudiness, particularly during the summer, combine to give a large diurnal temperature range near the ground. The above factors also contribute to the formation of deep, strong nocturnal inversions. In the summertime under ideal conditions, these inversions may exceed 5,000 feet in height with temperature differences on a 250-foot tower usually greater than 10° F and frequently greater than 20° F.

The most significant parameters included in the diffusion climatology are low-level (100 to 500 ft) winds and the vertical temperature profile. Generally the winds and temperatures are correlated and show a diurnal variation somewhat in accordance with that which would be expected in a mountain-valley situation. During the night when inversions prevail, light northeasterly winds are observed. An hour or two after sunrise lapse conditions, i.e., a decrease of temperature with height, are established and shortly thereafter moderate southwest winds normally commence. To obtain a better understanding of local diffusion patterns which cannot be categorized as readily as the situation described above, detailed studies utilizing meteorological tower data and low level wind and temperature soundings are in progress at the NRTS.

Inasmuch as the operating areas of the NRTS are separated by large distances, two main weather stations, "WBO" in the south central part and "ANP" in the north central portion of the NRTS, and a minimum of four auxiliary stations have been in operation at all times. The locations of the auxiliary stations have varied as climatological research and forecasting needs at different locations on the NRTS have varied.

MESO–METEORLOGY

Large-scale synoptic features coupled with mountain-valley phenomena usually determine the weather observed over the NRTS. At the north end of the site, the effectiveness of this combination is diminished by the super-imposition of other local topographic effects. This portion of the NRTS is near the mouth of Birch Creek Valley, within six miles of the mountains, and is the lowest elevation of the general area. In addition, when the flow aloft is westerly, the north end is to the lee of the mountains.

A large spatial variation in temperature is noticeable, particularly in winter. Simultaneous observations at "WBO" and "ANP" have occasionally shown temperature differences in excess of 25° F during the cold part of the year. The high frequency of temperature contrasts of somewhat lesser intensity through the year combined with concurrent observations of opposing winds at the north and south ends of the NRTS led to the postulation of a "miniature front" (3). During 1953 and 1954 this front was the object of a detailed investigation; while extending the description of this phenomenon, it did not define the mechanisms creating the wind and temperature patterns observed.

A typical case of the opposing flows finds a wind with a southerly component at "WBO" and a wind out of the north at "ANP" (to be classified as opposing winds, their duration has to be at least four hours). The opposing winds are usually 10 mph or less. However, the relatively frequent occurrence of opposing winds, each with speeds in excess of 10

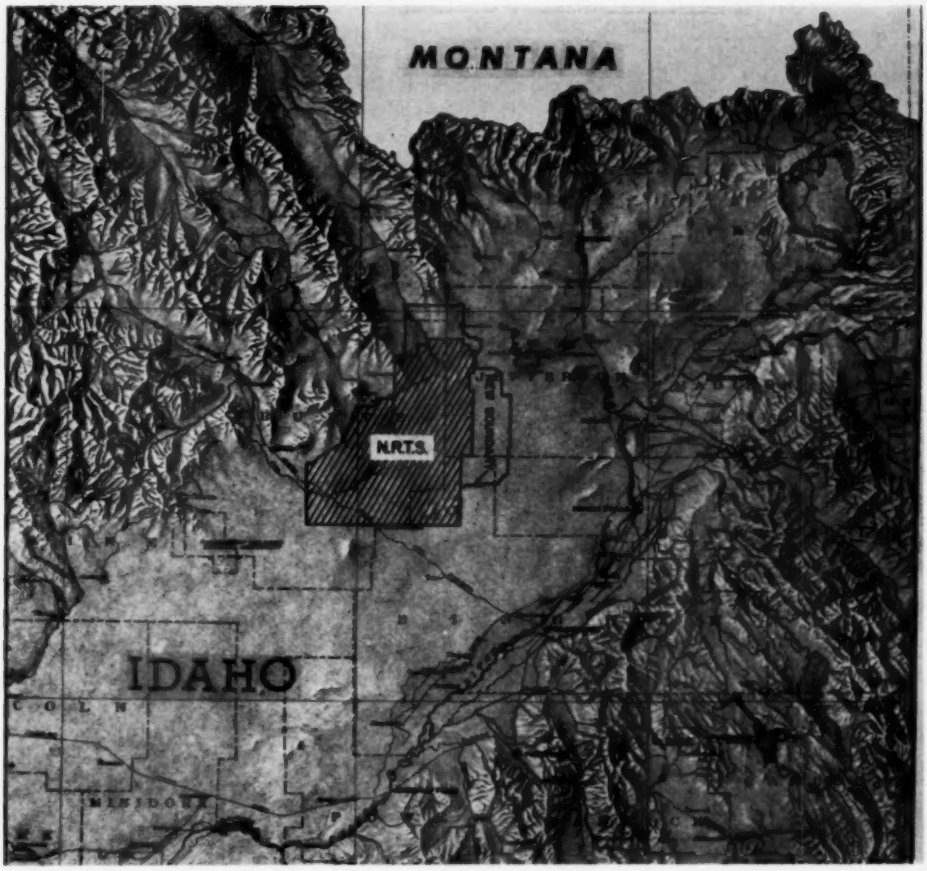


FIG. 2. A relief map of northeast Idaho shows the National Reactor Testing Site.

mph, has led another investigator (4) to postulate the possibility of a single eddy equal in size to the eastern portions of the Snake River Valley. It has also been suggested that the opposing winds are a dynamic effect resulting from air flow over the mountains aided by channeling. While the mechanisms involved in these contrasting temperatures and winds are not fully understood, the meteorologist has to try to anticipate the differences, particularly in his diffusion forecast. His most reliable tool is experience with the phenomena, but continued research may soon change this. The recent acquisition of five more meteorological towers will enable the study of the opposing wind phenomena to be intensified in the near future.

DIFFUSION FORECASTS

The parameters included in the diffusion forecasts are dispersion factors based on the lateral and vertical turbulence of the air containing the effluent. Also included are the downwind distance to, and relative concentration at, the point of maximum ground concentration of the effluent. The primary determinants of these parameters presently being used are the vertical temperature profile and wind speed and direction.

The importance of the vertical temperature profile can be seen in figure 3 (5; 6). This figure shows the five principal types of effluent plumes occurring with the temperature profiles shown at the left of the figure as a solid line. One glance at the different plumes

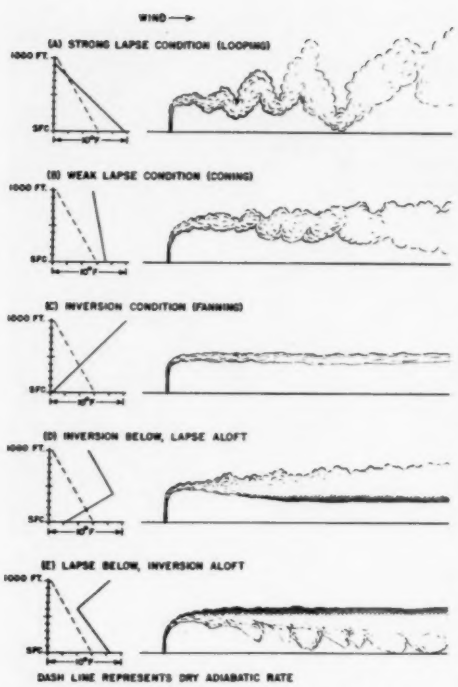


FIG. 3. The five principal types of effluent plumes occurring with different temperature inversions.

and one can realize the changes that would occur in the values of the previously mentioned parameters issued in the diffusion forecasts as the temperature profile changes throughout the day.

The diffusion forecasts are employed to schedule certain reactor operations where dilution of an effluent is deemed necessary. Health physicists of contractors operating nuclear facilities as well as those of the AEC and the U. S. Public Health Service position their sampling and monitoring equipment in accordance with the predicted diffusion conditions. On occasions when aircraft sampling is determined to be feasible and profitable, the meteorologist suggests flight patterns for the aircraft based on predicted diffusion parameters. Another frequent operation calls for the meteorologist to locate areas for optimum radiological monitoring several hours or days after an effluent has been released.

RESEARCH AND DEVELOPMENT

The importance of diffusion at the NRTS is shown in the fact that most of the major research and development projects conducted by this office have been concerned with diffusion and related meteorological parameters. Eight of these investigations are worthy of special note.

Early in the diffusion studies utilizing radioactive tracers, unique instrumentation was employed. Sky scanners (7), which are collimated gamma detectors devised by the Health and Safety Division of the AEC, Idaho Operations Office, were used to obtain the lateral variance of elevated radioactive plumes. The more recent sampling has been done with crystal gamma scintillation counters in airplanes. The most significant result to date has been that the dispersion factors assumed in the NRTS operational forecasts for the moderate to strong wind-temperature lapse case were found to be satisfactory for distances of several miles.

To study the short range diffusion of a plume from an elevated point source in greater detail, fluorescent tracer tests using uranine dye in a manner discussed by Robinson et al. (8) were conducted. These tests represent the most elaborate diffusion experimentation carried out at the NRTS.

A solution of powdered dye and water was forced to the top of a 150-foot meteorological tower by air pressure. Here, in a specially constructed nozzle, the solution was mixed with a large volume of air at high pressure to convert the solution to an aerosol. To collect the dye, 100 high volume air samplers were used on six arcs 40° to 60° wide and extending outward as far as 11,000 feet. The 150-foot meteorological tower was highly instrumentated (fig. 4) to collect information on vertical wind and temperature profiles as well as the turbulence of the air flow.

To obtain a complete budget of the dye released, as well as vertical plume concentrations, the five 100-foot towers shown in figure 1 were installed for the current series of diffusion tests.

Four other investigations were designed to obtain a better knowledge of the meteorological parameters which affect diffusion. These included low-level wind soundings using double-theodolite tracking of balloons for greater accuracy, low-level temperature soundings using tethered blimps, the previously discussed miniature front, and the East Butte study where temperatures on an isolated

butte were compared to free air temperatures at a comparable height over the valley floor. Greater detail on the behavior of low-level winds and temperature profiles was obtained from these studies, but the inversion tops were frequently above the height limit (1,700 feet) of the temperature-sounding equipment.

The two remaining projects to be discussed deal with instrument development. Cooperating with private contractors, an all-weather, all-purpose bivane (9) and a low-level, low-cost temperature sounding device (T-Sonde) (10) were designed.

The bivane shown in figure 4 was designed to measure the high frequency turbulence parameters of the wind flow in the horizontal and vertical planes simultaneously. Wind tunnel tests have shown that the response characteristics of the bivane enable it to faithfully indicate eddies of a scale important to the diffusion of a plume. Coupled with a suitable recording unit, this system is providing information to correlate wind statistics to diffusion.

As previously indicated, past temperature sounding with tethered blimps to maximum heights of 1,700 feet above the plain did not always reach the tops of the inversion layers. Since the heights and intensities of inversions are critical in diffusion forecasts, the T-Sonde was developed to overcome this height limitation. The T-Sonde is essentially a modified radiosonde transmitter. Everything except the basic transmitter and the temperature circuit is removed from the original radiosonde. In addition, the temperature circuit has been modified to obtain increased accuracy. The complete train sent aloft consists of a 300-gram, helium-filled balloon, a small ratchet release mechanism, a parachute, and the T-Sonde unit. The T-Sonde transmits a continuous signal of the temperature which may be read from the receiving equipment continuously or at any time interval. The T-Sonde is positioned by double triangulation using two theodolites to get height and distance from the release point. It is hoped that additional development work will enable the double theodolite tracking system to be discontinued. The T-Sonde is ideally suited for obtaining temperature profiles below 5,000 feet due to the high degree of accuracy obtained by the instrument and the low initial and operational costs. Depending primarily on sounding heights required and upper winds, a high rate of recovery of the T-Sonde units is possible. Since a parachute is included in the T-Sonde train for safety reasons, the slow rate of descent usually prevents any damage to the transmitter. Until damage does occur,

(*Continued on page 203*)

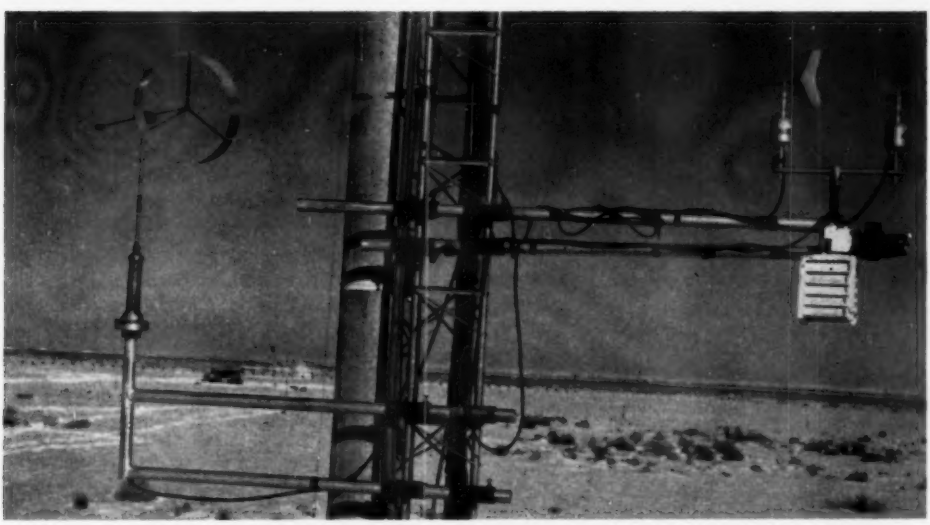
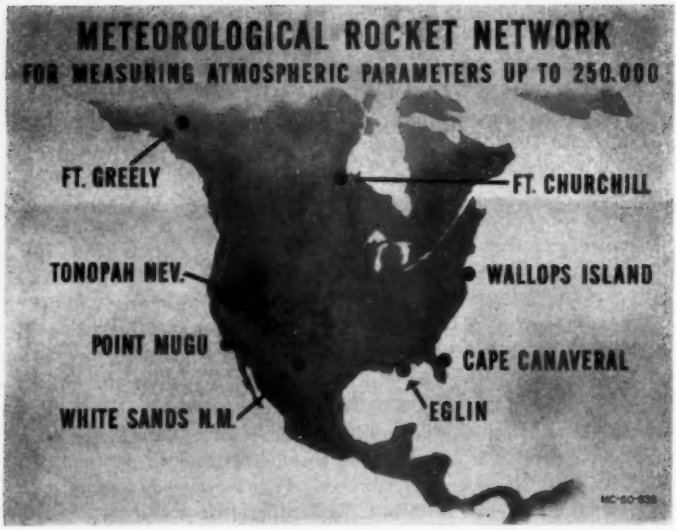


FIG. 4. A section of the 150-foot meteorological tower: at left is bivane, and at right precision anemometer and windvane along with temperature sensors.



H. J. AUFM KAMPE, *U. S. Army Signal Research and Developmental Laboratory, Fort Monmouth, N. J.*

IN the Fall of 1958 at an American Meteorological Society meeting in El Paso, Texas, the writer told the audience during a round-table discussion that the U. S. Signal Corps had been very encouraged by the results of the special balloon network which it had started in close cooperation with the Air Weather Service and the Weather Bureau. Now the Signal Corps had invited the other Dept. of Defense agencies, as well as the National Aeronautics and Space Administration and the Weather Bureau, to participate in a joint synoptic meteorological rocket network which should give synoptic meteorological data to at least 200,000 feet. It was also mentioned that since these rockets had to be fired from rocket-proving grounds, the Meteorological Working Group of the Inter Range Instrumentation Group (IRIG) had been approached to cooperate.

All agencies approached enthusiastically responded and a synoptic meteorological rocket network has now been established. And what is even more important, it seems to function very well because of the excellent cooperation among the different agencies involved.

Such a network does not run by itself, of course, and close coordination among all people concerned is necessary. Therefore, two groups have been created which work together very closely to guarantee that the tax payers' money is spent in the most economical way, i.e., that the maximum scientific value is obtained from these rocket firings. These groups are the Joint Scientific Advisory Group of the Meteorological Rocket Network (JSAGMRN) and the Meteorological Rocket Network Committee of the Meteorological Working Group of IRIG (MRNC–MWG–IRIG).

The members of the first group are research and development personnel of the Air Force, Army, Navy, NASA, Weather Bureau, and Sandia and Rand Corporations, who are concerned with the development of meteorological instrumentation, upper-air climatology, atmospheric dynamics, and the solar-terrestrial weather relationships. The chairmen of MWG–IRIG and MRNC–MWG–IRIG are also members of this group that designs the experiments, makes necessary analyses of the different sensors, and evaluates and publishes the composite data and the results of special experiments by the respective members.

The second group is composed of meteorologists of the proving grounds, whose responsibility it is to see that the rockets are fired on time, to coordinate the firings with

other elements on the proving grounds such as radar, and to collect and disseminate the data. So far they have done an excellent and very efficient job which is sometimes quite difficult since these meteorological rockets have, in the eyes of the range commander, a rather low priority compared to other projects. The fact that the chairman of this group, Mr. W. Webb, White Sands Signal Support Agency, is a member of the first group guarantees close coordination and cooperation between the two groups.

Originally, the following network stations were suggested: Patrick AFB and Eglin AFB, Florida; White Sands Missile Range, N. M.; Pt. Mugu, Cal.; Wallops Island, Va.; Tonopah, Nev.; Fort Churchill, Canada; and Fort Greely, Alaska. One or another station may be exchanged or added in this setup (see fig. 2). It is intended, for example, to have another station in Greenland; and possibly some European stations and those of other countries may contribute with their firings.

Two rockets that were extensively tested in the past few years are presently being used in the network firings. These are the Loki IIA (fig. 2) and the Arcas (fig. 3). Both rockets reach altitudes in excess of 200,000 feet if fired from sea level at an 85° elevation angle. The Loki as it is used in the network has 1 lb. of S-band chaff as its payload, i.e., aluminum or metallized nylon dipoles of 5-cm length (fig. 4). After the ejection of the chaff by using a pyrotechnical or mechanical

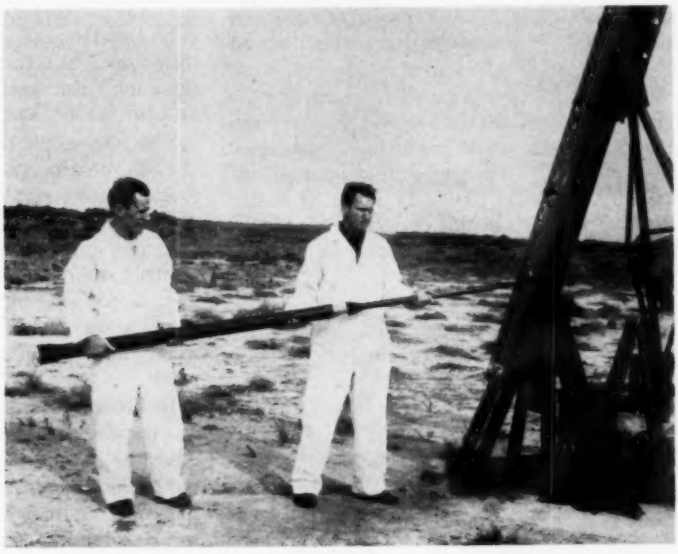


FIG. 2. LOKI II rocket.

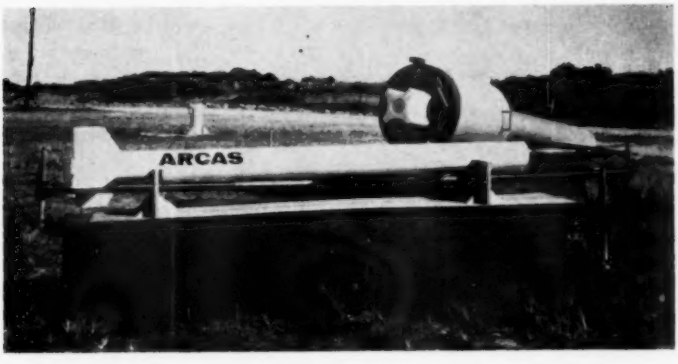


FIG. 3. ARCAS rocket.

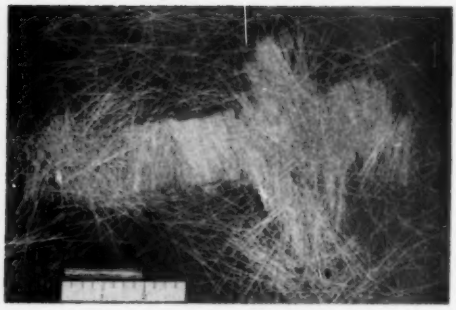


FIG. 4. Cylindrical aluminized nylon chaff used in LOKI II rocket.

time fuse at peak altitude, the chaff cloud is tracked by radar. Different trials have shown that the 0.12-mil nylon chaff seems to be best suited as a radar target between 200,000 and 100,000 feet. A radar plotting board record of a chaff-tracking is shown in figure 5.

Theoretical computation (Barr, 1960) yielded the fact that below 200,000 feet the chaff tracks the wind practically instantaneously and no correction to the wind as measured by the radar has to be made to obtain the true wind, since this correction (less than 5 mi/hr) lies within the accuracy of the system. Although the chaff is not a point target (since it more or less disperses on its way down), its track yields a good wind profile if the wind values are averaged over one-minute intervals.

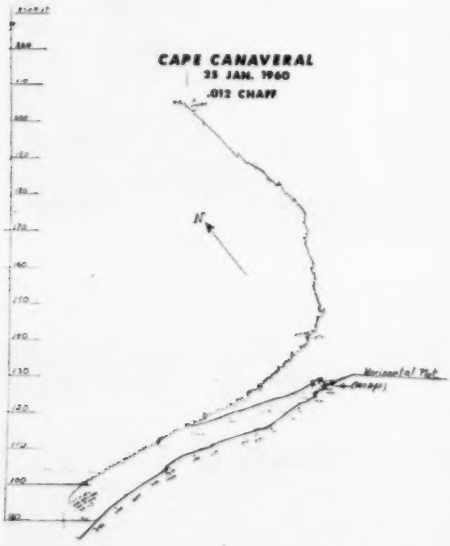


FIG. 5. Horizontal and vertical track of chaff as measured by radar (plotting board record). Figures at left represent thousands of feet elevation.

While the Loki measures only the wind, the Arcas will ultimately contain a radiosonde AN/DMQ-6 (fig. 6), specifically developed by the U. S. Army Sig. Research & Development Laboratory [USASRDL] and produced by Atlantic Research Corporation for use with this rocket and the AN/GMD-2 tracking system. As an interim solution, the White Sands Signal Support Agency had modified the AN/AMT-4 (the balloon radiosonde) which is used in connection with the AN/GMD-1 and a radar tracking the metallized 15-foot silk parachute. The AN/DMQ-6 as well as the AN/AMT-4 rocketsondes presently measures only the temperature, using a 10-mil bead thermistor; but the AN/DMQ-6 has provisions for other sensors. It is planned to add pressure, ozone, and humidity sensors.

The purpose of the network is:

1. To obtain synoptic upper-air data on a routine basis.

2. To investigate special features of the dydynamics and thermodynamics of the layer between approximately 100,000 and 200,000 feet, as for example: explosive warming and —at stations like White Sands Missile Range where the Loki reached 280,000 feet—tidal winds.

In order to accomplish these objectives it was decided to start with daily synoptic measurements during one month of each season at the stations already mentioned. To determine the effect of tidal forces, at least six rockets will be fired on one or two days a month during the 24 hours. Also, more than one rocket will be fired when there is any indication of an explosive warming in the stratosphere. Depending on their availability, the Arcas and Loki rockets may be fired alternately.

The first pilot network was started in October 1959 at Fort Greely, Fort Churchill, and Point Mugu. The main purpose of these firings was to find the shortcomings in the overall system and the operation. The next series of firings was carried out between the middle of January and the middle of February, 1960, at Fort Churchill, Point Mugu, and Wallops Island. Fort Greely has been

abandoned for the time being since the radar there is incapable of acquiring the chaff. For the spring and summer firings, Patrick Air Force Base, Florida, and Tonopah, Nevada, have joined the network. The data are now being evaluated. While they are by no means completely satisfactory with regard to quantity and quality, they look very encouraging, both with respect to wind and temperature. The raw data are being sent to the National Weather Records Center at Asheville, North Carolina.

The result of some test firings at White Sands Missile Range in March 1959, using Loki rockets, shown in figure 8, gives some idea of what can be expected from the network firings. The network data will give a time series at one station as well as a three-dimensional wind and temperature field composed of synoptic data from all stations.

The writer believes that with the synoptic meteorological rocket network a new era of meteorology has commenced.

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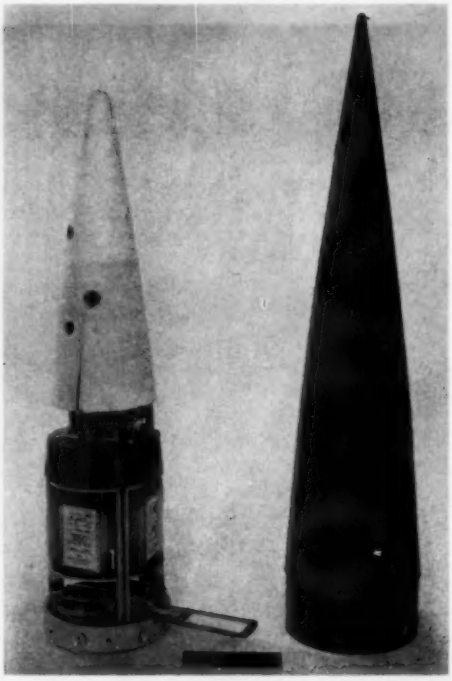


FIG. 6. Radiosonde Set AN/DMQ-6 for ARCAS rocket.

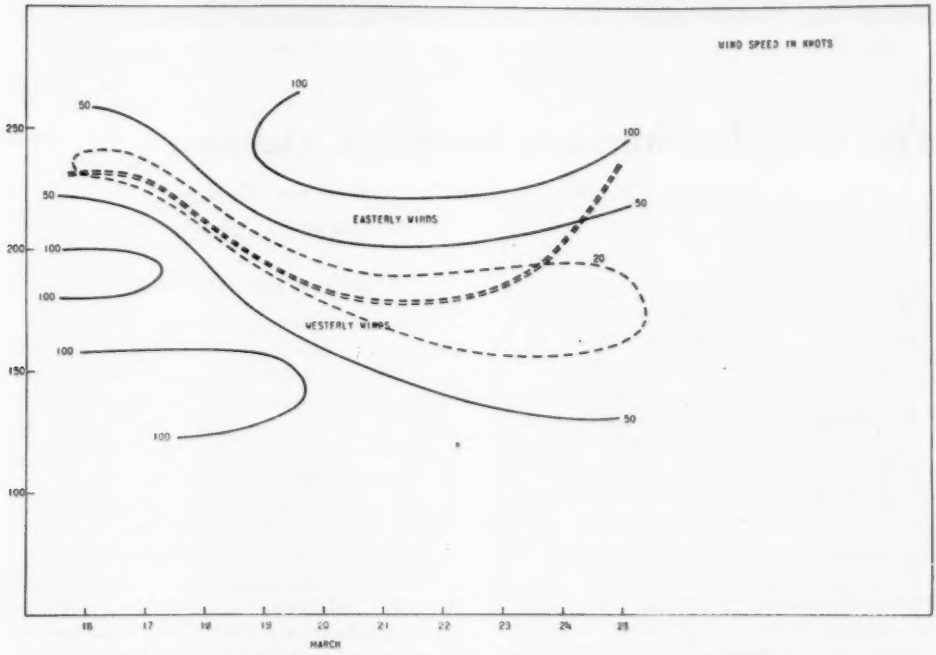


FIG. 7. Winds as measured with LOKI II, White Sands, N. M., 16–25 March 1959.

Monte Sano Mountain, Huntsville, Alabama, after the ice storm of 2 March 1960. Photo by F. Vaughn, courtesy *The Huntsville Times*.

The 1960 Ice Storm In Northern Alabama

BAKER B. WILLIAMS, *U. S. Weather Bureau, Huntsville, Alabama*

AN unusual ice storm occurred in north-central and northeastern Alabama on 2 March 1960. The storm was unusual in the severity and duration of icing for this section of the country and in the unique situation of icing on higher elevations, but none on lower levels over the entire north-central and northeastern section of the state. In fact, this condition extended into portions of southeastern Tennessee, northern Georgia, and northern South Carolina. The ice storm occurred in a major storm system which brought into the area a combination of abundant precipitation and air temperatures just above freezing in valleys and just below freezing over ridges.

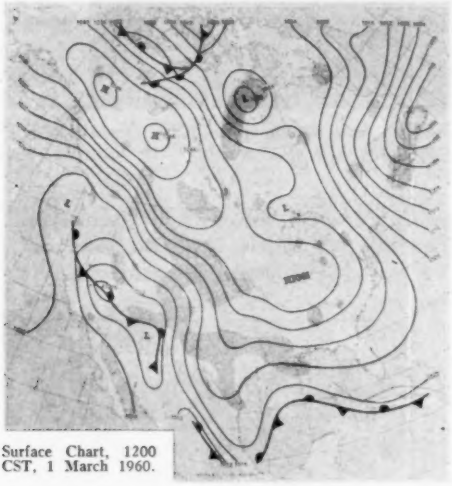
SYNOPTIC SITUATION

Early on 1 March 1960 the surface chart indicated no rapid or radical changes. A high pressure system with very cold air was centered over Missouri and moving eastward about 30 knots. A quasi-stationary front with stable waves extended from the Atlantic Ocean westward along the southern tip of Florida into Mexico. A trough with a stationary front extended from Mexico northwestward off the coast of Oregon (fig. 1).

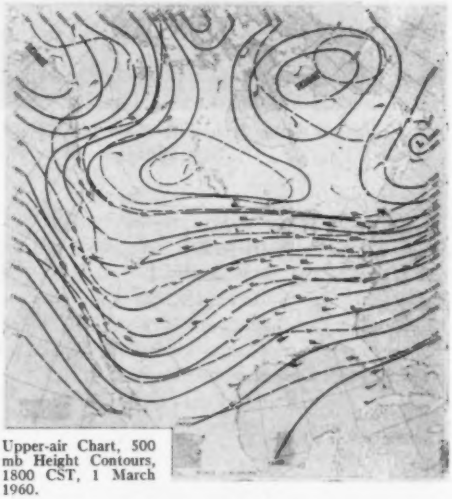
The upper-air charts on 1 March 1960, however, indicated conditions favorable for storm development. The 850-mb chart showed rapid warm advection over the Southern

Plains States and Southern Rockies. The 500-mb chart indicated a vigorous short wave over California early on March 1st which moved to near the Arizona-New Mexico Border by 1800 CST (fig. 2). At the same time, a jet stream of over 125 knots at 38,000 feet extended from near Presidio, Texas, to Arkansas where it increased to over 150 knots and flowed eastward to South Carolina. The jet stream moved southeastward the following 12 hours and extended from southern Texas northeastward over Louisiana, Mississippi, and northern Alabama at 0600 CST/2nd. Conditions were favorable for an active wave to develop on the quasi-stationary front, and most likely area for development was over the northwest Gulf of Mexico.

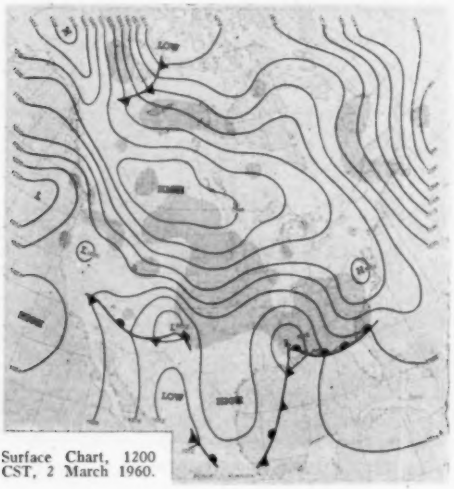
It was apparent on the surface chart at noon of March 2nd that a major storm had developed in the northwest Gulf of Mexico (fig. 3). This storm continued to develop and move northeastward the next twenty-four hours. By 0600 CST/3rd, the storm was centered in the Huntington, West Virginia area. At this time a rapidly developing wave near Norfolk, Virginia, which spawned six hours earlier over southern Georgia, was absorbing the available energy. In six hours this secondary circulation became the major storm off Virginia (fig. 4).



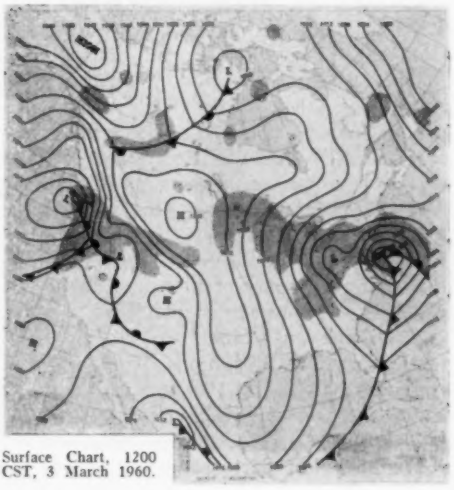
Surface Chart, 1200 CST, 1 March 1960.



Upper-air Chart, 500 mb Height Contours, 1800 CST, 1 March 1960.



Surface Chart, 1200 CST, 2 March 1960.



Surface Chart, 1200 CST, 3 March 1960.

Ice-capped Green Mountains show freezing level of storm on 2 March 1960. View from Monte Sano Mountain facing south. Photo by A. R. Hanson.

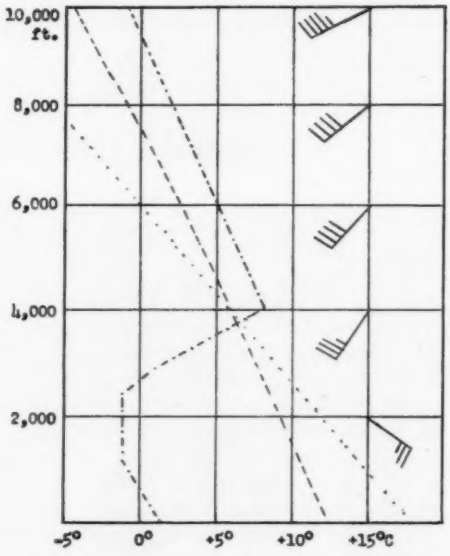
As the primary storm moved out of the Gulf of Mexico, it spread a sheet of ice from one-half to one inch in thickness from the higher elevations of north-central and northeastern Alabama eastward over southeastern Tennessee and northern Georgia. The secondary storm moved northeastward off the coast of New England and produced record snowfalls over Rhode Island and Eastern Massachusetts.

TOPOGRAPHY

Two ridges from the Appalachian Mountains extend southwestward into northeastern Alabama. One ridge ends in the Huntsville area. The other ridge extends to the Birmingham area. Elevations along the ridges are generally 1,000 to 1,600 ft msl. The northwestern portion of the state is relatively flat. The Tennessee River flows between the two ridges to about seven miles south of Huntsville and thence west-northwestward to the northwest corner of Alabama. The river valley is generally 500 to 700 ft msl.

Since icing in the Huntsville area was fairly representative of conditions over north-central and northeastern Alabama during the ice storm, remarks will be confined mainly to Huntsville area.

For the most part the mountains in the vicinity of Huntsville are not very steep, except for a fairly steep ridge which extends in a north-south direction just east of the city



Wind and temperature in lower levels for Huntsville, Ala., 1300 CST, 2 March 1960. The dash-dotted curve denotes the temperature lapse rate; the dashed curve, the pseudo adiabat; the dotted curve, the dry adiabat.

proper. The northern end of the ridge, Monte Sano Mountain, is within the city limits. The ridge, which is 1,400 to 1,600 ft msl and 800 to 1,000 feet higher than the city proper, and a few hills to the west place the major portion of Huntsville and the municipal airport in a valley.

WHAT A DIFFERENCE A DEGREE MAKES

Light rain and sleet began at Huntsville Airport at 2216/1st. The sleet ended in fifteen minutes, but the rain continued throughout the following day with three and one-half inches accumulating.

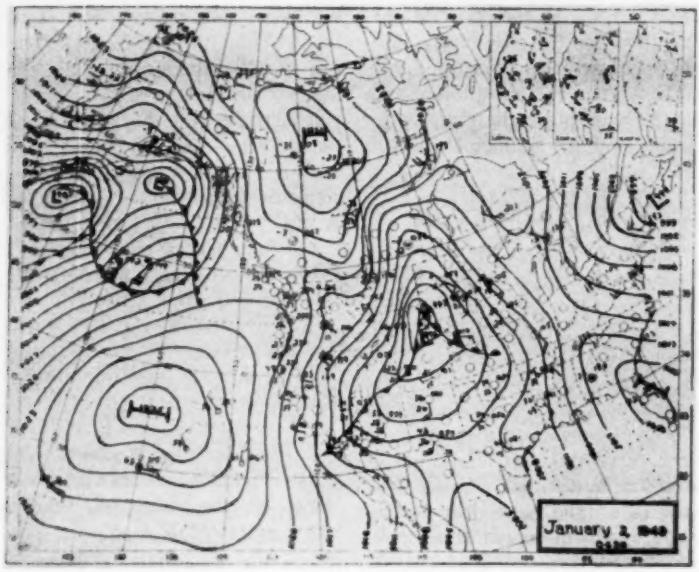
During the day of March 2nd, one could look at the surrounding hills and see a clear demarcation where ice was accumulating on higher elevations. A distinctly visible line formed two-thirds up the ridge just to the east of the airport with the upper third looking like a solid piece of ice. Icing continued on the ridge until 0100/3rd with one-half to one inch accumulating.

The temperature at the airport March 2nd ranged from 33° F to 38° F, but hovered mostly around the 34 degree mark. No icing occurred in the valley. At 1320/2nd a pilot reported temperatures aloft as follows: 2,000 ft msl −1° C, 2,500 ft −1° C, 3,000 ft +1° C, 4,000 ft +8° C, 5,000 ft +7° C. A chart shows the possible winds and temperatures in lower levels in this area at about 1300/2nd.

Life in the valley proceeded as usual during the storm, but for those who lived on Monte Sano life was quite different. As trees became encased in a thick shell of ice with long icicles, they bent, split, and snapped with the resounding crack of a shotgun. Telephone and power lines were out. The residents on the ridge rely almost solely on

(Continued on page 203)

Street scene on Monte Sano Mountain, Huntsville, Ala., after ice storm of 2 March 1960. Photo by F. Vaughn, courtesy *The Huntsville Times*.



Surface Chart, 0430 PST, 2 January 1949, showing north-south surface isobars over California and Nevada.

Freezes and Their Effect Upon the California Citrus Industry

R. W. DURRENBERGER, *Professor of Geography, San Fernando Valley State College, Northridge, California*

THE climate of southern California is subtropical in nature and like similar regions in other parts of the world is subject to occasional periods of extreme climatic conditions. The greatest amount of damage to the extensive plantings of citrus in this area is the result of low temperature conditions.

A number of factors are involved in determining the extent of damage which any given period of low temperatures will produce. A few of the most significant follow:

1. The ambient temperature of the air is most important. Damage to the fruit of the lemon may occur at temperatures below 30.5° F. Oranges are damaged at temperatures below 28° F to 29° F. Wood and foliage are injured at lower temperatures.

2. The length of time which low temperatures persist is a significant factor. If the temperature drops below the danger point for only a short period of time, no damage is likely since the fruit temperatures will remain above the air temperatures.

3. Rain or snow during a cold spell increases the amount of damage since water collecting on the fruit increases the rate of heat loss from the fruit. Snow also may collect on the trees and cause branches to break and split.

4. The type of weather preceding and following a severe freeze appears to be of great importance. Cool, cloudy weather before a freeze helps to condition the tree to withstand low temperatures. Similar weather following a freeze appears to help the tree to recover better than do sunny skies and high temperature conditions.

Periods of low temperatures have been

called frosts or freezes. The distinction between the use of these terms is not a clear-cut one. As used by the Fruit-Frost Service of the United States Weather Bureau, a freeze is identified as a wide-spread condition of temperatures below 32° F where no well-defined surface temperature inversion exists.

Frosts occur every winter in some part of southern California and are most frequently associated with clear skies, dry air aloft, and light winds. Such conditions are conducive to rapid loss of heat from the earth with the consequent chilling of air in contact with the ground and the formation of pools of cold air as a result of air drainage. The term, frost, has also been applied to the low temperatures associated with invasions of polar air which do not qualify as freezes because of the existence of a temperature inversion in the lower levels.

A frost will produce a smaller amount of damage than a freeze since the total area affected is smaller and because frost protection devices are more effective when an inversion exists. In addition, plantings on the upper slopes, which are generally the coldest areas during freezes, are, for the most part, unprotected.

Freezes have been observed and recorded by the settlers of California as far back as 1821. The mission fathers indicated that the period from January to March of that year was unusually cold. In January 1854 there was ice skating in San Francisco; the south fork of the American River froze solidly enough for pedestrian traffic; and a temperature of 19° F was recorded at Sacramento. The winters of 1878–79, 1879–80, 1882–83 were unusually cold and damage to citrus and other crops was reported from various parts of California. These early freezes helped to establish in broad outline the areas in which citrus could be grown, but the acreage of citrus involved during this period was small.

The first freeze to affect extensive plantings of citrus was that of January 1913. This was perhaps the most damaging freeze experienced in this area. Minimum temperatures were low; a major portion of the citrus was being grown in the colder districts; and frost protection devices were crude and few in number. Freezes in January of 1922, 1937, and 1949 also caused extensive damage to citrus. The 1937 freeze is generally classed as the most severe period of cold weather ever to occur in southern California. (At Pomona there were only three days with maximum temperatures above 60° F during the whole month of January, and the duration of temperatures below 32° F was long.)

The quantity and quality of the information available about each of these freezes varies considerably. Minimum temperature data are available for all freezes since 1850, but the reliability of much of this data for the earlier freezes is questionable. Surface weather maps may be studied for the past four freezes. Upper-air constant pressure charts are available only for the January 1949 freeze.

A detailed examination of all available material reveals certain common characteristics for the freeze periods. With reference to the synoptic conditions, it may be said that a freeze-type situation does exist. Each of the last four freezes has been associated with a low pressure area located over southwestern United States and with a high pressure ridge which extended from the Arctic Ocean to the tropics. The constant pressure charts for the 1949 freeze show a low pressure trough aloft over the Western States, while the winds aloft during the 1937 freeze indicated that a similar pressure pattern existed at that time.

There appears to be a definite correlation between the orientation of the trough aloft and of the surface low pressure area with the temperature of the cold air pulled into southern California. With the surface low and the trough aloft located over the coastal areas, the principal flow of air into California is of a marine nature, and the resultant temperatures are not particularly low. If the surface low and the trough aloft are located well to the east of California, the citrus districts of southern California are on the fringes of the cold air flow, and those districts located in Santa Barbara and Ventura counties escape damage to a great extent.

The synoptic situation in January 1937, which produced the most severe freeze in modern times, had a well-developed surface low situated over northwest Mexico, an intense surface high moving straight south out of Canada, and a strong northerly flow of air aloft over California. During this freeze the winds at the 12,000-foot level averaged from 50 to 75 mph. This deep, rapid flow of air

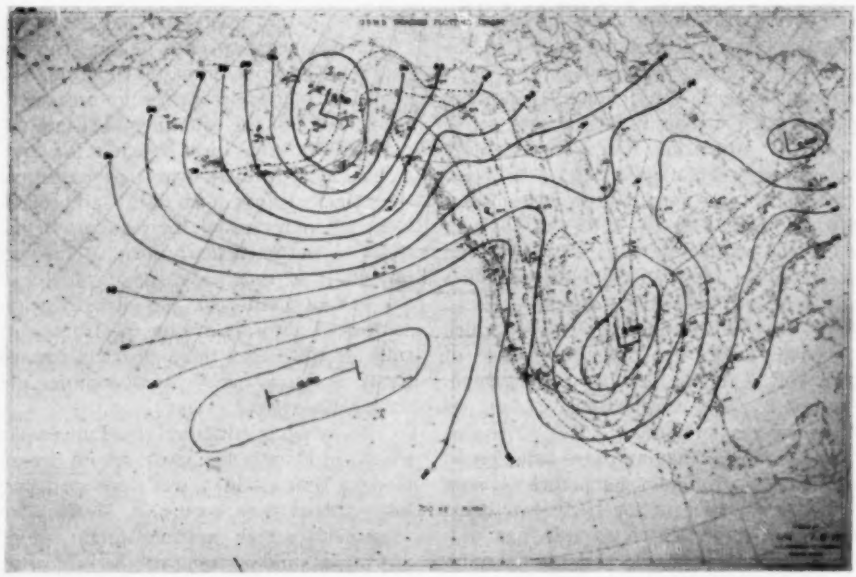
from polar source regions appears to be required in order to produce a major freeze in southern California.

Low temperature conditions may exist during any of the winter months, but a majority of the freezes occur in January. Only one period of cold weather in February is discussed in the literature relating to damage to citrus. This was in 1883. Several cold periods not generally classed as freezes have occurred in November and December. On the basis of previous records, it appears that the first twenty days in January represents the period in which freezes are most likely to occur.

Minimum temperatures in various parts of the citrus districts are recorded on different dates during a freeze because of differences in topography and exposure to wind. On the upper portions of the slopes the lowest temperatures usually occur on the first or second night of a freeze, while on the lower slopes and in the valley bottoms the lowest temperatures occur during the latter nights and are a result of the drainage of cold air into these areas.

Most of the anomalous situations which develop during freezes are a result of the unpredictable wind currents associated with the flow of air over the mountains and through the mountain passes to the sea. The air flow down the river valleys is an extremely turbulent one and is effective in keeping minimum temperatures within the stream of air comparatively high in comparison to that of the air outside its path. Such wind currents create problems for citrus growers since the minimum temperatures in the groves on the fringes of such an air flow will fluctuate rapidly up and down making orchard heating difficult.

Although each particular freeze has varied somewhat from its predecessor, all have certain common characteristics such as similarities in the pressure patterns, high wind speeds, and lack of a temperature inversion during the first several days. From the evidence available, it appears safe to assume that we may expect freezes in southern California at intervals of ten to fifteen years in the future.



Upper-air Chart, 750mb surface, 0700 PST, 3 January 1949, showing north-south pressure contours (solid lines) over California and Nevada, and dome of deep cold air aloft (dotted lines) over the Plateau States.

Reactor Testing

(*Continued from page 191*)

the unit may be reused with only a change or recharge of batteries.

In addition to the previously mentioned projects, the need for automatic collection and storage, at a single point, of the large amount of weather data being recorded throughout the NRTS has long been recognized. Having all the weather data placed on storage tape for research and climatological purposes and tabulated for immediate operational use would have advantages far outweighing the cost of such a system. With the weather data on tape for machine data reduction and calculation many research studies can be conducted in a small fraction of the time required by hand methods. In addition, digitalization of the meteorological parameters would not only allow additional information to be collected but would allow technicians, who now spend many hours daily collecting and recording data, to spend their time more profitably on other projects.

The first phase of this project should be completed in the next few months. This will include digitalization of most of the meteorological parameters presently being recorded at "WBO," including surface and tower temperatures and temperature differences—surface and tower winds presented in vector form rather than as direction and speed separately—solar and terrestrial radiation—dew point—and the horizontal and vertical fluctuations of the wind indicated by the bivane. The next part of the overall project will be to complete the design of the equipment needed to digitalize the information from a meteorological research tower.

CONCLUSION

The needs of nuclear industry require a diversified meteorological program of operations and research to forecast and study the transport and diffusion of pollutants in the atmosphere. This is not only an important and useful part of the greater overall AEC program, but is also a part of the national meteorological research effort.

Acknowledgment

The author is deeply indebted to G. A. DeMarrais, now at the Weather Bureau Office, Robert A. Taft Sanitation Engineering Center, Cincinnati, Ohio, who initiated and outlined the report, and made preliminary drafts of some of the sections.

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Alabama Ice Storm

(*Continued from page 199*)

electricity for heat and light. Roads were blocked by ice, trees, and wires.

Except for some shady spots, the ice had melted one week after the storm, but many years will pass before the scarred and damaged trees are replaced. Damages from the ice storm in Alabama to timber, buildings, equipment, utilities, poultry, hogs, cattle, and dairy industry were estimated to be near $20 million.

The WEATHER PAST / November

1	1716	Dark Day in New England—Rev. Mather sent account to Royal Society.
	1861	Hatteras hurricane battered Union fleet attacking Carolina ports.
2	1743	Ben Franklin's "Eclipse Hurricane" unlocked key to Northeast storms.
	1810	New York's 7″ snowfall permitted earliest sleighing in the streets.
3	1890	Los Angeles: 96°, highest ever in November.
4	1927	Great Vermont Flood—2-day rain of 9″+ put rivers of western New England over banks—Winooski Valley devastated—84 dead in Vt.
5	1894	Famous "Election Day" snowstorm began in Conn.—10″ deep.
6	1953	Early snow Northeast—27″ Penna., 8″ Phila., 4″ Wash.—78 mph R. I.
7	1940	Narrows Bridge at Tacoma (Galloping Gertie) collapsed in 31 mph wind.
8	1955	San Francisco: 84°, highest ever in Nov., peak of 4-day heat wave.
9	1913	Famous Great Lakes Storm—200 lives lost Lake Huron—Erie 28.61″—Buffalo 80 mph—Cleveland 22.2″ snow—Pickens, W. Va. 36″.
	1926	Tornado in Charles Co., southern Maryland, killed 17 persons.
10	1835	Severe storm swept Lower Lakes "of all sails"—many sailors drowned.
	1915	Great Bend, Kan: tornado killed 11; $1 million loss, greatest then known.
11	1940	Armistice Day Storm—worst ever in Upper Lakes—49 dead in Minn., 59 Mich.—17″ snow Iowa—blizzard Minn. & Wis.—28.66″ Duluth.
12	1820	New England early snowstorm dropped 12″ over Mass. & Conn.
	1906	Craftonville, Calif: 105°, hottest ever for U. S. in November.
13	1820	Earliest freeze-up of Hudson River at Albany (1786–1959).
	1880	Severe Santa Ana and sandstorms in Calif. caused much damage.
	1933	First great "Dust Bowl Storm" spread pall from plains to New York.
14	1753	Violent easterly gale at New York City flooded wharves and cellars.
15	1900	Watertown, N. Y: lee shore snowburst dropped 45″ in 24 hours.
16	1958	Tucson, Ariz: 6″ snowfall, greatest for any month, any year (1892–).
	1959	Severest November cold wave in history—Lincoln, Mont. had −53° for lowest ever in U. S. in Nov.—Helena's 21.5″ snow, record storm.
17	1869	SW hurricane winds swept west slopes Green Mts. in Vt., much damage.
	1927	Tornado Alexandria & Wash, D. C.—93 mph—waterspout 90 min. later.
18	1873	Severe NE storm Ga. to N.S.—Portland 28.49″—Eastport 64 mph.
19	1921	The Dalles, Ore: 54″ snow and sleet blocked Columbia River highway.
20	1869	Second 1869 wind swept Vermont & New York—blew train off tracks.
21	1798	Long Storm of 1798—4-day snow piled up 36″ Maine–N.H., 12″ NYC.
22	1720	Early severe cold Phila.—Dr. Colden: "my ink freezes as I write."
23	1912	Late season hurricane off Hatteras—later hit SE Newfoundland.
24	1812	SW hurricane winds Phila. & N. Y.—buildings unroofed, ships sunk.
25	1950	Great Appalachian Storm in Northeast—record high storm damage—108 mph Newark—57″ snow Pickens, W. Va.—28.88″ Akron, Ohio—7.78″ rain Slide Mt., N. Y.—record Nov. cold Midwest & Southeast.
26	1949	Northwest: severe wind storm (67 mph) followed by very high floods.
27	1898	*Portland* Storm—ship sunk off Boston in heavy snow & whole gale.
	1938	Second heavy snow in 3 days in Northeast—12″ on ground in N. J.
28	1888	Hurricane passed near Nantucket, later crossed Nova Scotia.
	1950	Moderately severe freeze in Florida—20° Tallahassee, Nov. record.
29	1921	Central New England had 4-day ice storm—paralyzed Worcester area.
30	1875	Severe early cold: Buffalo +2°, New York City +7°, Nov. records.
	1896	Great November cold wave: −45° at Pokegama Dam, Minn.

The WEATHER PAST / December

1	1831	Coldest December closed Erie Canal—NYC Dec. mean 22°, lowest 1788–.
2	1925	Hurricane off Georgia, later crossed Hatteras as tropical storm.
	1950	Late season tornado killed 4 in Madison & Bond Cos. in Illinois.
3	1791	Salem, Mass: "Nivis tempestates per totum diem," Rev. Bentley.
	1856	Severe blizzard-type storm in Kansas & Iowa—pioneers suffered.
4	1786	First of two great early Dec. snows: Morristown 18″, New Haven 20″.
5	1886	Big snow in Southeast: Rome 18.5″, Knoxville 22.5″, Montgomery 11″.
6	1950	Duluth, Minn. had greatest 24-hour snowstorm in history with 23″.
7	1740	Greatest flood on Conn. River in 50 years, on Merrimac in 70 years.
8	1938	La Mesa, Calif: 100°, warmest ever for U. S. in December—Los Angeles registered 91.7° for only 90° reading ever in December.
9	1786	Second great snow in 5 days: Morristown 21″, New Haven 17″.
10	1876	New York City's earliest below-zero reading: −2°.
11	1932	San Francisco's coldest day: min. 27°, max. 35°, both all-time lowest.
12	1856	Second 1856 "blizzard" in 10 days again hit Iowa, Kan. & Minn. settlers.
13	1878	Los Angeles: 30°, "considered" lowest ever there in December.
14	1780	Severe cold wave commenced "The Hard Winter," toughest ever in U. S.
15	1839	First of Triple Storms of 1839—"Wreck of the Hesperus"—NE whole gale swept Mass. Bay—28.96″–24″ snow fell inland.
16	1835	New England's bitterest day: −17° Hanover (1330), −4° Boston (noon) with WNW gale—Great New York Fire that night, frozen pipes, hoses.
17	1743	Charleston-Savannah buried in greatest snowstorm known to settlers.
18	1780	First big snowstorm of "The Hard Winter"—17″ at New Haven.
19	1924	Riverside R. S. (Yellowstone Park) Mont: −59°, lowest U. S. for Dec.
20	1836	The famous "Sudden Change" in central Illinois—cold front at noon caused quick drop from 40° to zero—"chickens frozen in tracks."
21	1836	Prof. Loomis' storm—1st International Study Period in meteorology.
22	1839	Second of Triple Storms—25″ Gettysburg, "worst in 30 years."
23	1775	The Snow Campaign at Reedy River, N. C.—24″ in 24-hrs. hit camp.
	1811	Long Island Sound Blizzard—zero, NE gales, 12″ snow—ships lost.
24	1796	Famous cold day: Cairo −7.5°, both Miss. & Ohio frozen, Lex. Ky. −13°.
	1868	Severe Florida freeze—fruit damaged—Jacksonville 20°.
	1870	Severe Florida freeze—fruit damaged—Jacksonville 19°.
25	1776	Washington crossed Delaware, marched on Trenton in NE sleet storm.
	1778	The Hessian Storm at Newport—zero, 18″ snow, NE gales—many died.
26	1909	Phila's deepest snow 21″—severe coastal storm N. England—high tides.
	1947	New York City's deepest snowstorm—25.8″ at Battery—32″ in suburbs—traffic completely paralyzed—snow removal cost $8 million—27 died.
27	1876	Tenn: heaviest snow since 1843, McMinnville 14″, Memphis 8.5″.
28	1839	Third of Triple Storms—24″ snow Hartford-Worcester—28.77″ Boston—whole gales swept coast—studied by Redfield and Espy.
29	1830	Very deep snow (Kansas City 3′, Peoria 2½′) began "Year of Deep Snow."
	1894	Severe Florida freeze—fruit frozen—considerable wood damage.
30	1917	Great cold wave in East: −13° at NYC was all-time record then.
	1933	Bloomfield, Vt: −50°, lowest in modern records for New England.
31	1775	Americans assaulted Quebec in blinding snow, ended in disaster.
	1863	Blizzard swept Midwest—Peoria: −11°, W gale, 12″ snow at 2400.
	1933	Los Angeles: 7.36″ 24-hr rain set stage for county's worst flood.

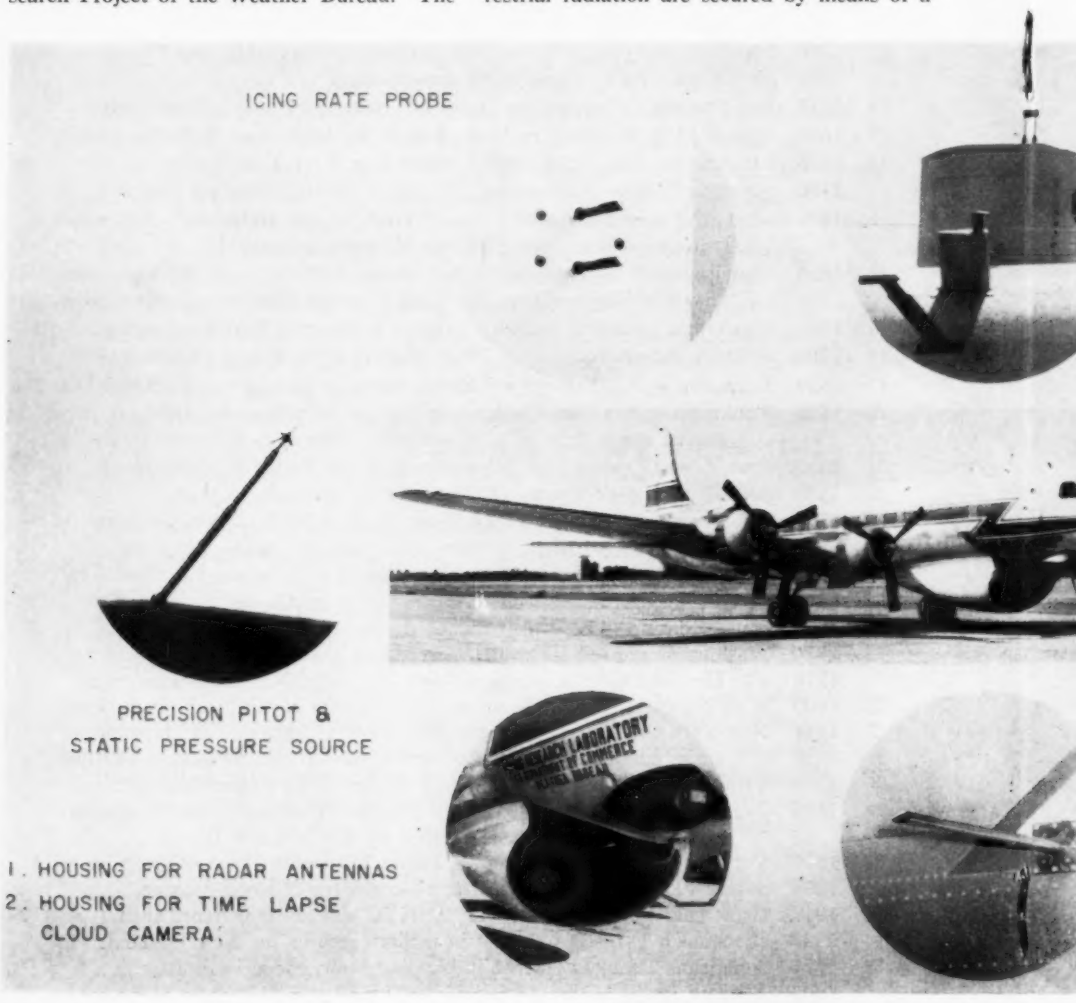
Review of Recent Hurricane Research

ROBERT CECIL GENTRY, *Acting Director, National Hurricane Research Project, Miami*

DATA COLLECTION

THE West Indies network has been expanded by adding a station at Bogota, Colombia. The West Indies network is a cooperative effort of several foreign countries and our own. The government of Colombia is establishing this station at Bogota with assistance from the National Hurricane Research Project of the Weather Bureau. The addition of this station makes a total of nine which have been established since the start of the intensified effort for research on hurricanes.

Radiometer soundings are being taken at selected Caribbean stations during this hurricane season. These observations of the terrestrial radiation are secured by means of a



DC–6 Meteorological Probes

Miami

small device attached to the radiosonde box. The observations are conducted as part of a joint project between the U. S. Weather Bureau and the University of Wisconsin. It is expected that this series of observations over the Caribbean will provide information on the important problem of the radiation processes in the atmosphere and will afford insight into the energy processes which prevail during periods of disturbed weather which sometimes lead to the formation of hurricanes. The infra-red radiation studies at the University of Wisconsin are directed by Dr. V. Suomi who has been a leader in the program which is now securing radiation observations from satellites. The radiation data collected during orbits of the satellite Explorer VII are being used for comparison with the data collected from the radiometer soundings. The soundings are made at the following stations: Weather Bureau Airport Stations at Miami, Florida, and San Juan, Puerto Rico; Cooperative Hurricane Observation Stations at Curacao, Grand Cayman, and Sint Maarten; the Naval Air Station at Trinidad, and Albrook Air Force Base, Canal Zone.

IN ASCENDING ORDER

1. VORTEX THERMOMETER.
2. ROSEMOUNT TOTAL TEMPERATURE PROBE.
3. PAPER TAPE LIQUID WATER CONTENT METER.
4. HOT WIRE TYPE WATER CONTENT METER. (Above housing)

AIR INTAKE & EXHAUST FOR INFRA-RED HYGROMETER SYSTEM

REVERSE FLOW THERMOMETER

Data recording pods are again being carried by the hurricane reconnaissance planes of the Air Force stationed at Bermuda. This is a cooperative effort of the Air Weather Service and of the Weather Bureau. These pods are modified wing tanks which contain photopanels for photographically recording the data measured during flights into hurricanes by the Air Force planes. Data collected in this manner during the 1959 season have proven to be very valuable additions to the data library of the National Hurricane Research Project. This is another of the means which is being used to extend the primary data collection of NHRP at minimum expenditure and risk.

The three new research planes instrumented by the Weather Bureau for the National Hurricane Research Project have been used during this season for reconnaissance of hurricanes and other circulations in the tropics. The three planes are: two DC-6's which are rented by the Weather Bureau, and one B-57 jet which is bailed to the Weather Bureau by the Air Force. These airplanes are successors to the three aircraft formerly furnished and operated by the Air Weather Service of the Air Force, two B-50's and one B-47. The new planes' instrumentation systems have been modernized based on the experience of the three-years operation of the older reconnaissance aircraft.

New weather search radars, WSR-57, are either installed or in the process of being installed at Brownsville and Galveston, Texas; Lake Charles and New Orleans, Louisiana;

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Apalachicola, Tampa, Miami, Key West, and Daytona Beach, Florida; Charleston, South Carolina; Wilmington, North Carolina; Washington, D. C.; Atlantic City, New Jersey, and New York, N. Y. Older but equally powerful radars are operated by the Weather Bureau at Nantucket, Massachusetts; Hatteras, North Carolina; and San Juan, Puerto Rico. Weather radars are now scanning the coastal areas from Portland, Maine, to Brownsville, Texas.

When a storm is approaching, Weather Bureau radar specialists have been manning radar sites of the Air Defense Command as necessary to augment coverage of the Weather Bureau's own radar. Arrangements have also been made to obtain observations from radars at the Air Force Atlantic Missile Range stations.

The Weather Bureau's hurricane warning service continues to depend on Air Force and Navy reconnaissance planes for reports on location, intensity, and movement of hurricane and tropical storms at sea. Detachment 3 of the Air Force 55th Weather Reconnaissance Squadron, with headquarters at Kindley Air Force Base, Bermuda, and the Navy Hurricane Hunters of the Airborne Early Warning Squadron Four, which is now based in Puerto Rico, have continued to make their reconnaissance sorties into tropical cyclones.

CURRENT RESEARCH

One experiment being conducted at Miami this summer is designed to determine if air motions in the lower and upper layers of the troposphere can be used to ascertain when rain should occur. The mean winds for the layers 3- to 10,000 and 37- to 42,000 feet are used in computing divergence and vorticity for those layers for southeastern United States and the Caribbean area. The hypothesis is that convergence in the lower layer and divergence in the higher layer should correspond to areas of heavier rainfall because such patterns would cause larger amounts of ascending air motion. Likewise, convergence in the upper layer and divergence in the lower layer should be associated with sinking motions and little or no precipitation. To test the hypotheses the vorticity and divergence patterns computed from the winds are compared with amount of rainfall activity observed by the long-range radars. So far, results are encouraging.

The main hurricane forecasts issued by the Weather Bureau for the general public are for 12 to 24 hours in advance, to warn people to evacuate threatened areas and to make last minute preparations prior to the onslaught of hurricane force winds. Because of the time lag inherent in observing, collecting, and analyzing data, and in preparing hurricane advisories, it is necessary to make a forecast for a period extending 30–36 hours after the time of data observations, in order for the forecast to be for 24 hours after it is received by the public. The National Hurricane Research Project is working in cooperation with the Travelers Research Group to develop a technique for forecasting hurricane motion for 36 hours in advance. This technique is being checked during this hurricane season.

The climatology of North Atlantic tropical cyclone movements has been brought up to date by George W. Cry, Office of Climatology, U. S. Weather Bureau. He has prepared a paper which contains tabulations by months of 24-hour tropical cyclone movements in 68 selected areas covering most of the North Atlantic Ocean, and that section of North America affected by these storms. The frequency of tropical cyclone passages through each area, and month and year of storm origin or detection in each area are also shown. Nine additional charts are presented in this study to depict those portions of the tropical cyclone tracks containing complete loops and the areas of recurvature or change in direction of storm movement.

"A numerical experiment on the development of a tropical cyclone," by Dr. A. Kasahara of the University of Chicago, has recently been completed. This report deals with a model of a tropical cyclone constructed on the basis of the conservation of momenta

(radial and tangential), mass, water, water vapor, and heat in the hydrostatic system. The horizontal and vertical eddy exchange processes for momentum, moisture and heat are included in the equations in order to incorporate the planetary frictional layer into the model. The effects of the surface boundary (Prandtl layer) are simulated by the boundary conditions for the equations which permit the evaluation of surface drafts, sensible heat transport, and the evaporation of water vapor from the earth's surface. Energy sources of the model are the latent heat of condensation released during the ascent of moist air and the sensible heat transported from the ocean surface. The balance of total energy may be obtained with the sinks of energy due to frictional dissipation and atmospheric radiation processes.

Recent studies at the University of Miami, Radar Laboratory, have been directed toward better interpretation of radar presentations of tropical cyclones. A recent study made by Mr. Harry Senn of that group has attempted to identify typical radar patterns which may be useful in forecasting hurricane motion or hurricane intensification. In several storms of the last ten years, echoes that resemble a carrot in shape have occurred along the forward periphery of a hurricane. In the studies that Mr. Senn has made, these "carrot-shaped" echoes have been typical of storms which have moved in similar fashion. Preliminary indications suggest that identification of these or other typical echoes may be useful in forecasting hurricane motion or in identifying changes in hurricane motion at an early stage.

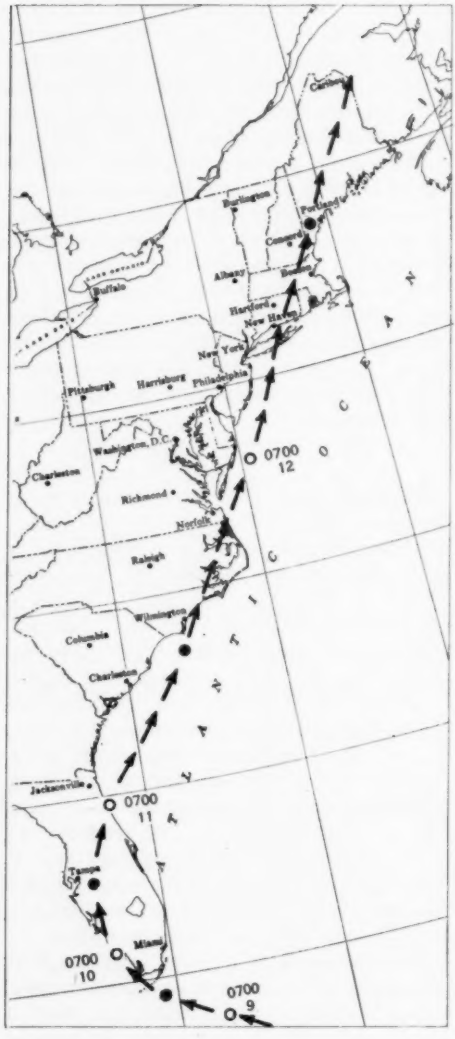
A typhoon research group in Japan was enlarged several months ago following the typhoon disaster which killed so many people in the islands of Japan. This group has been working in cooperation with the National Hurricane Research Project of the United States for some time and has prepared a film to be used for educational purposes in Japan. While the movie, of course, has a Japanese sound track, a considerable portion of the footage of the film was taken either by the National Hurricane Research Project of the United States or by the Air Weather Service of the U. S. Air Force. Copies of this film have been sent to the National Hurricane Research Project as partial fulfillment of some contract work being done by the Japanese group.

The Hydrologic Services Division of the Weather Bureau has been working on presentations of different parameters in hurricanes (both actual and idealized) in such a manner as to assist the U. S. Corps of Engineers in assessing surge-producing potential of storms. These studies indicated that, at least along the northern portion of the Atlantic seaboard, it is entirely possible for middle latitude storms to have a higher surge-producing potential than hurricanes at the same latitude. In consequence, work is now being done on development of "typically severe" parameters of middle latitude storms (winds, pressure, etc.). These studies are being made to help the engineer make the choice of a "design storm," one against which it will be economically justifiable to construct coastal protective works.

In recent years there have been cases of tornadoes being associated with hurricanes. To determine how serious a problem this may be to the forecaster, studies are being conducted of tornadoes associated with hurricanes and tropical storms by R. C. Schmidt, Chief District Meteorologist, Washington National Airport, Weather Bureau, and Banner I. Miller, one of the research meteorologists at the National Hurricane Research Project, Miami. Some preliminary indications of the study by Schmidt suggest that the chances of tornadoes in hurricanes appear to increase when air from a second source penetrates well into a hurricane circulation and that they are less likely when the air circulating through the hurricane is composed of homogeneous tropical air. However, since tornadoes and hurricanes have been reported in only a small percentage of the cases when non-homogeneous air enters into the circulation, further stratification will be attempted. In some of the storms studied for the Florida area by Miller, it has been determined that the hurricanes have occurred in the homogeneous air.

Hurricane DONNA in Florida

KEITH BUTSON, *State Climatologist, U. S. Weather Bureau*
Gainesville, Florida



The Track of DONNA over the American mainland, 9–12 September 1960. Open circles indicate position at 0700 EST; closed circles at 1900 EST.

HURRICANE DONNA, destined to be the first full-blown hurricane to strike the Florida peninsula since the Miami storm of October 1950, was first detected in the tropical North Atlantic on 2 September. After travelling some 2,000 miles west northwestward and developing winds up to 150 mph near the center, DONNA made her fateful turn toward a more northerly course on 8 September—a course which was to carry her devastating winds, heavy rains, and accompanying high tides over the middle Florida Keys during the night of the 9th–10th, up the southwest peninsula and then inland over Ft. Myers in the early afternoon of the 10th. DONNA moved northward toward Lakeland then northeastward and out into the Atlantic early on the 11th. Although winds decreased slightly in intensity during the overland journey, DONNA re-entered the Atlantic as a still well-organized storm and underwent some intensification soon after leaving Florida. In her wake were 12 known dead, attributable either directly or indirectly to the storm, and mute testimony of her tremendous destructive power. Of the 12 lives lost, six were by drowning, four by heart attack, one by auto accident and one by electrocution. The low death toll speaks well for the storm warning system. Pertinent meteorological data for some Florida stations are listed in the table below.

Storm damages ranged from very severe on the middle Keys and the southwest coast to relatively minor at northeast Florida points north of the storm track. Damages and rainfall, in general, were significantly greater and noticeable farther from the center on the right side of the storm track than on the left—a situation which became more and more evident as the storm moved northward. Damages by wind and tide on the Keys ranged from almost complete destruction of all but

the most stout buildings in the Marathon-Tavernier vicinity to loss of roofs, broken windows, water damages, and battered boats and dock facilities at other points throughout the Keys.

The Overseas highway was overflowed by tides at a number of places and the road completely disappeared at bridge approaches at several points. The pipeline used to supply the Keys with fresh water was broken in at least three places, requiring water to be brought in by truck or boat. Tides at Tavernier were reported to be about 18 inches lower than those associated with the famous Labor Day 1935 storm on the Keys. Tides in the Everglades City—Naples—Ft. Myers Beach area were estimated 4 to 7 feet above normal and perhaps even higher in some places. At Naples, tides pushed inland to the center of the city, damaging buildings and smashing docks along the 8-to-10 block intrusion. Everglades City, a town that had been largely evacuated, was also inundated by tides and about 50 per cent of the buildings in that city were destroyed by tides and wind. Tides farther north were progressively lower as the winds in advance of the storm center were offshore on the Gulf coast and the center itself was travelling over land. On the Gulf coast north of Bradenton and on the Atlantic north of the Palm Beaches, tides were mostly 1 to 3 feet above normal and tide damages were relatively minor. Tides in the Miami-Miami Beach area ran mostly 2 to 4 feet above normal and tidal flooding was not a major contributor to the over-all damages.

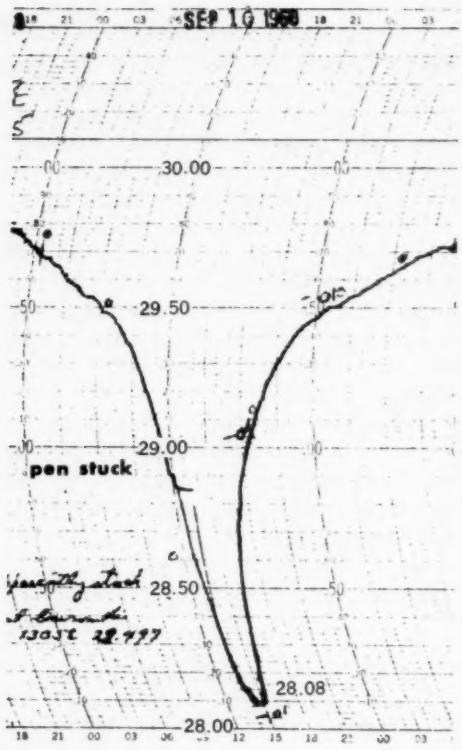
High winds, with recorded gusts of 135 to 150 mph on the middle Keys, 120 mph at Ft. Myers, and 80–100 mph over a large portion of the central peninsula and in the Miami area, toppled thousands of trees, demolished many of the weaker buildings, blew off or damaged roofs, and shattered windows of

HURRICANE DONNA PRELIMINARY METEOROLOGICAL DATA—FLORIDA STATIONS—SEPT. 1960

Station	Date	Pressure		Wind (mph)				Rainfall	Remarks
		Low	Time	Fastest mile	Time	Gusts	Time		
Clermont	11	28.50	0130			97			Wind lull 0200–0215
Craig (Keys)		27.4–27.5							Range of 3 private barometers
Daytona Beach WBAS	11	28.73	0445	58 ESE	0300	86 ESE		4.58	
Daytona Beach FAA	11					99 ESE	0342		
Ft. Lauderdale	10	29.51	1700	60	1630				
Ft. Myers	10	28.08	1427	92 NE		121	1331	4.95	Eye over station 1420–1531
Jacksonville WBAS	11	29.20	0820	46 NE	0554	67	0715	4.43	
Key West WBAS	10	29.27		70					
Lakeland WBO	10	28.60	2320	68 NE	2135	90(est.)		6.61	
Lignumvitae Key		27.85							
Marathon	10	27.98		120*				12.10	
Miami WBAS	10	29.34		55		78		8.67	
Naples	10	27.97							3 to 4 feet water in city
Orlando WBAS	11	28.66	0236			69 ESE		4.47	
Sarasota	10					100			
Sombrero Light	10	27.89				150			
Tampa WBAS	10	29.11	2230–2310	62 N**	2140	75 N	2120	3.60	
Tavernier		28.80		120*					Anemometer needle solid against 120 mph pin for 45 minutes

* Anemometer will not register above 120 mph.

** Highest one minute wind.



Barograph trace at Ft. Myers, Florida, 10 September 1960, on a 108-hour barogram. Lowest pressure of 28.08"/950.9mb occurred at 1427 EST. "Pen apparently stuck" soon after 1200, but was freed well before minimum pressure. Courtesy, John W. Hayes, USWB, Ft. Myers.

scores of the more substantial buildings throughout the area affected. Wind-driven rain added materially to the over-all storm damages in those areas. Power and communications facilities failed throughout central and south Florida.

A large portion of the central peninsula citrus belt was subjected to the strong right side of the storm. Gusty winds uprooted or blew over trees on ridges and other unprotected locations, stripping the leaves off trees and blowing the fruit off. Preliminary estimates by the U. S. Department of Agriculture indicate grapefruit losses will run between 25 and 35 per cent of the state's crop and probably 5 to 10 per cent of the state's orange and tangerine crops were lost. Since all fruit was immature, none can be salvaged. The avacodo crop was hit very hard; most of the fruit was blown from the trees and the trees themselves sustained heavy damage.

Reported rainfall during this storm ranged from 5 to 10 inches in an 80-to-100-mile-wide band extending roughly 50 to 75 miles to the right of the storm track and 30 to 40 miles to the left of the track. Heaviest rains apparently fell on the extreme southern peninsula; reported totals in the Miami and south Dade County area were mostly 7 to 10 inches with a few totals near 12 inches. Rainfall data for stations south of Ft. Myers were apparently lost when the gages were either blown away or tipped over. North of Ft. Myers, reported storm totals were mostly 5 to 7 inches with the greatest amounts reported in the central and southern sections of the area. Few storm totals of more than 3 inches were reported from stations more than 80 miles east or more than 50 miles west of the storm track. It is believed the heavier rains on the southern peninsula were the result of slower storm movement in that area, hence the rains were of somewhat longer duration.

The rainfall flood potential of this storm was augmented by antecedent rains. Rainfall during the three weeks prior to DONNA totaled 6 to 10 inches over the affected areas, hence water tables and lake levels were relatively high just before the storm. Lake and stream overflow, especially on the central peninsula, forced evacuation of some homes. High waters also closed many roads and inundated considerable agricultural lands throughout the storm affected areas.

Comprehensive storm damage surveys are still in progress and no estimate of total damage will be available for some time. There is no doubt, however, DONNA was one of the most destructive hurricanes ever to strike Florida from the standpoint of property damage. In terms of loss of life and personal injuries, DONNA could have been much, much worse.

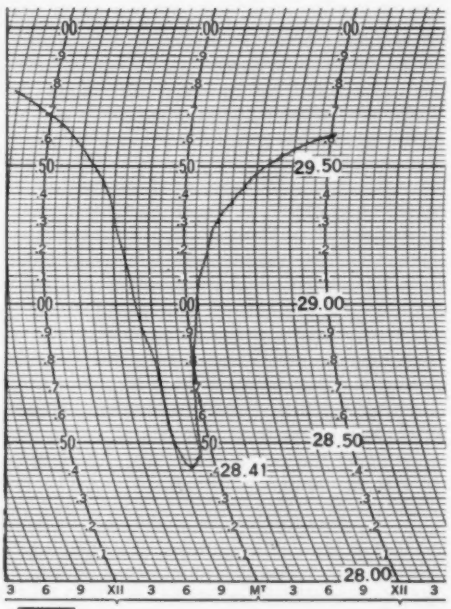
Hurricane DONNA in North Carolina

ALBERT V. HARDY, *State Climatologist, U. S. Weather Bureau*
Raleigh, North Carolina

THE center of Hurricane Donna moved from a position near Cape Fear at 2100 EST, 11 September 1960, in an almost straight line north-northeastward across eastern North Carolina, passing into the Atlantic Ocean again close to the Virginia line about 0500 the next morning. The storm center came inland near Swansboro and then moved very near to New Bern, Belhaven, and Elizabeth City, a path at all points so close to those of Connie and Ione in 1955 as to make the inhabitants of that region of the state feel singled out for this type of disaster. During the past decade at least five other tropical storms have taken nearly similar tracks across North Carolina: Barbara 1953, Carol and Hazel 1954, Diane 1955, and Helene 1958.

The outstanding characteristic of DONNA during its passage over North Carolina was the uncommonly large size of the eye. The central area of calm or variable winds was estimated at fifty to eighty miles in diameter, yet was so clearly marked by the characteristic breaking of clouds, permitting an occasional glimpse of the moon, as to prompt one newspaper reporter to refer to DONNA as "the storm with the beautiful eye." Periods of lull ranging from half an hour to two hours were reported from all of the following points in the vicinity of the storm path: Holden Beach, Oak Island, Wilmington, Camp Lejeune, Sneads Ferry, New Bern, Aurora, Oriental, Cherry Point, Washington, Belhaven, and Elizabeth City. The Weather Bureau Airport Station at Wilmington, North Carolina, estimated to have been ten miles to the west of center at the time of the storm's passage, experienced more than an hour of lull. Winds of less than 15 knots were reported simultaneously for some time from such well-separated points as New Bern and Cherry Point (20 miles) and later from Washington and Belhaven (25 miles).

Reports of lowest sea level pressure have been received from more than a dozen locations along or near the path of the storm center. Several of these are Cooperative Hurricane Reporting Network stations, having official aneroid barometers frequently checked by Weather Bureau inspectors; and the others, which belong to highly pressure-conscious coast dwellers, are kept reasonably well adjusted. Most of the pressure minima reported lie between 28.30 and 28.55 inches, mean sea level, or 958 to 967 millibars. Of those believed to be reliable, Belhaven had the lowest pressure, 28.30″/958.3 mb, from 0200 to 0245/12th.



A reconstructed barograph trace at Wilmington, North Carolina, 11 September 1960. Original data taken on a 12-hour barogram has been transcribed to a 108-hour barogram for uniformity. Lowest pressure of 28.41″/962.1mb occurred at 2150 EST. Courtesy, Sam F. D. Duke, USWB, Wilmington.

The highest wind gust at a regular Weather Bureau station was 97 mph from the northwest at Wilmington at 2355, more than two hours after the center of the storm had passed. Cooperative Hurricane Reporting Network stations at New Topsail Beach and Sneads Ferry reported gusts at "100+," the limit of the capacity of their instruments. At New Bern Federal Aviation Agency station, the highest gust was reported at 90 knots (104 mph). Newspapers gave wide circulation to reports of gusts to 120 mph and sustained winds at 80 mph at Manteo, but these have not been confirmed. Gusts to 94 mph from the south were recorded at the Weather Bureau Office at Cape Hatteras.

Tides are reported to have been four to eight feet above normal at various places along the coast at the height of the storm, with waves 15 to 20 feet in height. The southern and central beaches were hit at the time of normal high tide; in the north, the normal tide was on the way out at the height of the storm. Wrightsville Beach, a large and well-established area near Wilmington, is reported to have been inundated by a huge wave about 2100, while the winds were blowing close to 90 mph. The wave left about three feet of water in the police station, forcing evacuation of that facility. In some areas affected by the inland bodies of water which comprise such a large portion of eastern North Carolina, the greatest tidal effect was felt on the "backlash" of the storm, when winds shifting to northwest rapidly drove back toward the Outer Banks large quantities of water that had been backed up into the estuaries by the earlier easterlies. At Manteo, on historic Roanoke Island just inside the Outer Banks, where coastal storm effects are rarely felt at their worst, the wind shift was followed by a rise in water level of about three feet in fifteen minutes.

Hurricane Hazel is the reference by which most lay comparisons of hurricane effects are made in North Carolina, and there are many Tar Heels who stoutly maintain that DONNA was worse than Hazel. This is a matter of viewpoint, of course, and the report is only true in certain limited areas. The damage in the Atlantic Beach-Morehead City-Beaufort area was comparable to that of Hazel, and in some particular portions very likely worse. The Manteo-Nags Head area suffered greater damage from DONNA than from Hazel because the 1954 storm's path was too far west for the northern coastal area to feel its full fury. At its worst, however, DONNA was selective in its effects, and no general area suffered complete devastation. Some of the southern beaches of North Carolina were completely wiped out and swept clean by Hazel, which also caused major damage scattered inland over two-thirds of the State.

A tornado is reported by news sources to have moved along a path about half-a-mile wide and fifteen miles long near Elizabethtown in Bladen County, destroying several buildings and breaking or uprooting many trees. No information is available as to the direction of the path of this storm. Near Clinton, in Sampson County, another reported tornado demolished a dwelling and hospitalized its eight inhabitants. Both storms occurred several hours before the arrival of the main blow in North Carolina; the first tornado took place around 1400/11th, and the other about 1700. There were several other cases inland of locally destructive winds over limited areas.

Eight deaths have been attributed to DONNA in North Carolina: one person was electrocuted, three drowned, two crushed by falling trees, and two died in a traffic accident in which weather was a factor. An estimated 100 persons were injured sufficiently to require medical attention.

News sources report early estimates of crop damage between $16 and $17 millions, and damage to forests at $15 millions. No over-all estimate of property damage has been released, but several of the larger beach communities report damage of the order of $1 million each. It is apparent that the property damage will likely be declared in excess of the crop damage.

Hurricane DONNA in the Northeast

JAMES K. MCGUIRE, *Northeast Area Climatologist, U. S. Weather Bureau*
New York City

THIS article deals with what impressed the writer as the two most interesting features of DONNA's passage on September 12th up the Middle Atlantic coast into New England. These were the behavior of the wind field and the character of the center or "eye." The severity of the hurricane and the damage it wreaked were also remarkable. It does not seem necessary to dwell on these points here, as data has appeared in the press and in *Weekly Weather and Crop Bulletin*, 19 Sept. 1960.

It would be presumptuous to attempt an "explanation" of the features that will be discussed below. Only an exhaustive analysis of the abundant data collected on DONNA will achieve this. So, what follows is a brief descriptive account, not a research paper, and may require correction as the result of subsequent investigation.

The Middle Atlantic and New England States were mainly struck by DONNA's left-hand semicircle, usually the less dangerous one. Even so, winds of hurricane force affected the coastal belt and gales extended a considerable distance inland. As exceptions to the above, the entire hurricane circulation moved across Long Island into southern and east-central New England, while eastern Long Island, Rhode Island, and southeastern Massachusetts were swept by the right-hand or dangerous semicircle.

By the time the center penetrated into Connecticut, it had begun to fill. Lowest sea level pressures in the Cape Hatteras area and on Long Island were in the neighborhood of 28.40 inches; lowest in New England was 28.52 inches at the Blue Hill Observatory, Milton, Mass. Furthermore, the wind field decreased in intensity and changed shape strikingly, even before the center reached the Connecticut coast. Wind speeds remained very high, however, near the center and on the right-hand side in southern New England.

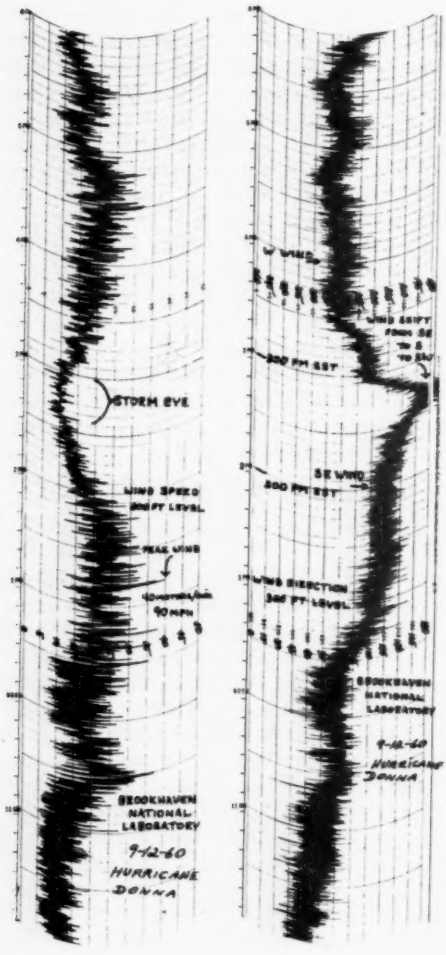
Peak gusts along the Maryland, Delaware, and southern New Jersey coasts had been in the vicinity of 100 mph during the morning. Similar speeds were experienced in the afternoon along the eastern portion of Long Island's South Shore and the Rhode Island-Massachusetts coast. At Montauk, L. I., the anemometer was pegged at 100 knots repeatedly during the hour from 1430 to 1530 EST. Block Island, R. I., reported a peak gust of 130 mph at 1615. Gusts of 90–100 mph were registered at Point Judith, R. I., before two of the three anemometer cups were blown off. Gusts of similar force raked the Cape Cod area. The peak gust observed in the entire Northeast occurred at the 663-foot exposure of the Blue Hill Observatory: 140 mph from the south-southeast at 1632 and 1637. The interior of southern New England was swept by gusts up to 85 mph to the east of the center's path, while peaks were about 65 mph for a short distance to the west.

Most of Connecticut, however, experienced less severe winds. The peak gust in this State seems to have been 75 mph at Putnam in the northeastern corner. From this value, the 81 mph peak at Providence, R. I., and the Point Judith observation, one would assume comparable winds along the Connecticut shore, at least from New London eastward. At Groton, on the contrary, the peak gust was reportedly 50 mph. Other peak gust readings in the State ranged from 64 mph at Middletown and 58 mph at Bridgeport to 50 mph at Windsor Locks and 46 mph at New Haven. Even allowing for some uncertainty, the zone of hurricane-force gusts was oddly "bent" around most of Connecticut.

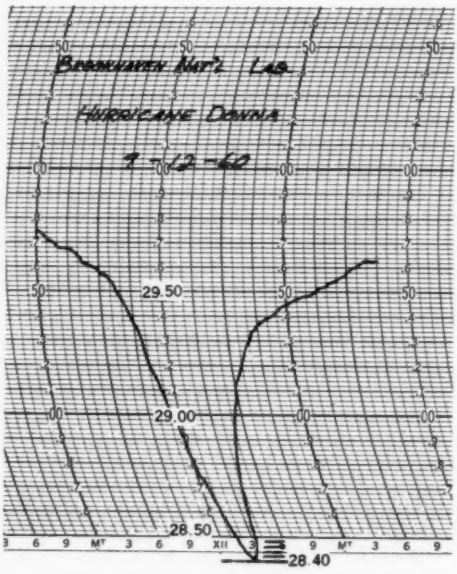
This point was closely linked in time and space with the second interesting feature displayed by DONNA in the Northeast. When it passed near Wilmington, N. C., about 2150 on the 11th, the eye was 50–75 miles in diameter: that is, 50 miles northwest to southeast and 75 miles northeast to southwest. On the following morning, locations on the Del-Mar-Va Peninsula experienced a near-calm with sunshine through breaks in the clouds.

The western side of the center also brushed the New Jersey coast. About 10 miles inland from Atlantic City, the winds which had previously gusted to 71 mph lulled to 15–25 mph between 1015 and 1100, and a special bulletin from the local Weather Bureau pointed out that "the eye of the storm is quite broad as evidenced by the light winds which have been reported along the southern New Jersey coast."

The eye probably extended westward to the North Jersey shore and the New York City area. At the Weather Bureau Office in downtown New York City, the barograph trace described a sharp "V" but there were about 20 minutes when the pen hovered before reaching the minimum point of 28.65 inches at 1350 (EST). The heavy rain slackened and there was a wind lull between 1300 and 1400 before the northwest gales struck. Reports from Long Island suggest that the eye extended eastward almost to the Brookhaven area, or about 65 miles east-northeast of WBO, New York. The Brookhaven charts indicate that the hurricane center moved to the west of this station. The minimum sea-level reading of 28.375 inches on the mercurial barometer at Brookhaven is the lowest reported in the Northeast at this writing, although unofficial barographs in the Babylon, L. I. area dipped to about 28.35. The unusual size of the eye was also noticeable in New England, where the office of the State



Dual Aerovane charts show wind data on 12 September 1960 at Brookhaven National Laboratory, Long Island, N. Y. Exposure at 300-foot level. Wind speed on left graduated in meters/second; wind direction on right graduated from 0° to 180° with return traverse 180° to 360°. Time is EST. The decrease in wind speed and shift in direction is clearly discernible between 1430 and 1500. Courtesy, Maynard E. Smith, Leader Meteorology Group, Upton, N. Y.



Barograph trace at Brookhaven National Laboratory, Long Island, N. Y. on 12 September 1960. Barogram is 108-hour. Lowest pressure on adjacent mercurial barometer was 28.375″/960.85mb at 1450 EST. Courtesy, Maynard E. Smith.

Climatologist at Boston reported that "the diameter of DONNA's eye may well have been upwards of 50 miles, according to a number of near-simultaneous reports from locations separated by that distance."

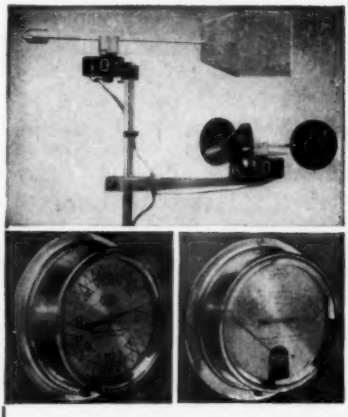
In his classic book, *Hurricanes*, I. R. Tannehill writes that "the average diameter of the calm center is approximately 14 miles, though there are wide variations in individual cases." No exhaustive search of the literature has been made, but it seems safe to affirm that the eye of DONNA, at least from Cape Hatteras to New England, was exceptionally large and was probably unprecedented in size for a hurricane in this region.

Even more interesting was the change in shape of the center. Between 1300 and 1500, the orientation of the center's major axis shifted from northeast-southwest to almost north-south. It may be speculated that this central change was linked with the absence of very high winds over most of Connecticut, in the sense that the circulation in the left-front quadrant was diminished by, or along with, the axial shifting.

What really happened will of course only become clear after detailed analysis. Certainly, as the radar observations indicated, DONNA's center was complex: there may have been more than one "eye" within the large oval discussed here. A final point is the suggestion that DONNA may have assumed or was in the process of assuming extra-tropical characteristics. If so, the circulation was even more complicated. At any rate, it was a memorable and most interesting storm.

Acknowledgments

For the information on which the foregoing is based, thanks are due to the U. S. Weather Bureau State Climatologists for Maryland-Delaware, Pennsylvania, New Jersey, New York, Connecticut-Rhode Island, and central and northern New England, and to the meteorologists in charge at Wilmington, N. C., Atlantic City, N. J., New York, N. Y., New Haven, Conn., and elsewhere along the coast; to the meteorology staffs of Brookhaven National Laboratories, Rutgers University, Mitchel AFB, Grumman Corp., the "Long Island Weathermen," and others.



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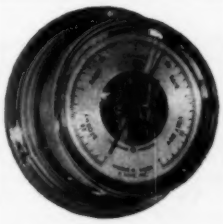

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Data by Office of Climatology, USWB.

Summer Presents a Varied Fare

DAVID M. LUDLUM

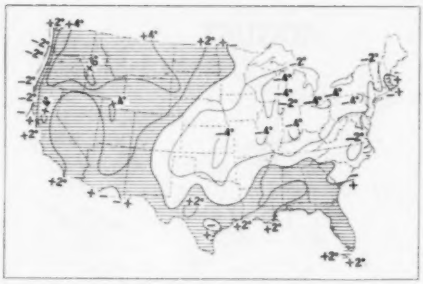
The air flow across North America exhibited a fairly uniform pattern throughout the month of July with a rather long wave length between pressure features. A trough in the eastern Pacific Ocean south of central Alaska along 150° W was separated by approximately four thousand miles from a trough over the Atlantic seaboard states running from Quebec through New England to west-central Florida. For the greater part of the month a strong ridge dominated the intervening space with its axis over the western Prairie Provinces of Canada and the Plateau States. Here anticyclonic conditions prevailed throughout the period and gave the area a rather torrid early summer.

The westerly flow index remained above normal as these conditions became established, but monthly departures from normal were generally small and positive. For one period from the 3rd to the 9th the flow index dropped slightly below normal as a large anticyclone built up over the central part of the country to perform a blocking role by shunting winds over the Pacific States into the southwest and over the Eastern States into the northwest.

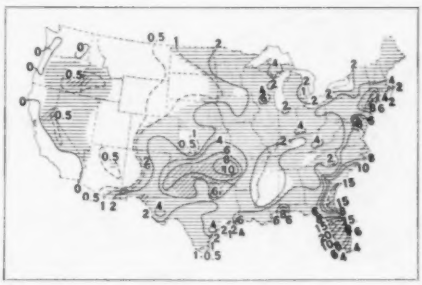
The trough along the Atlantic seaboard had its base in the upper Hudson Bay region of Canada eastward to northern Labrador. This northern area provided the seat of great cyclonic activity during the month, and several times the pressure dropped as low as 986 mb/29.10" as an upper-air vortex took form over the cool waters of Hudson Bay.

To the west, surface pressures between Alaska and Siberia ran far above the seasonal normal for that Arctic Ocean area, and often a long ridge connected with the anticyclonic feature over the Western States. Seven distinct high pressure areas were produced here, and their southeasterly march at intervals of three to four days gave the weather over the northern Plains, the Midwest, and the Northeast its distinctive polar flavor for this July. Practically all anticyclones moved between the Great Lakes and the Ohio Valley, either eastward to New England or southeastward to Virginia and the Carolinas, each being accompanied by a fresh outbreak of polar continental air.

The first half of July divided into two anticyclonic periods. The first developed over the north-



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

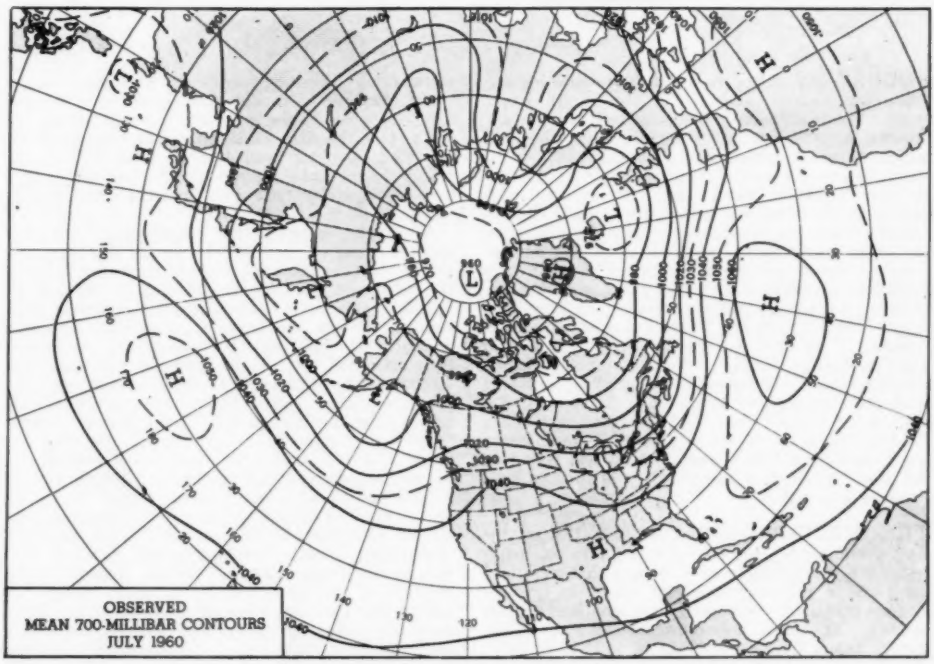


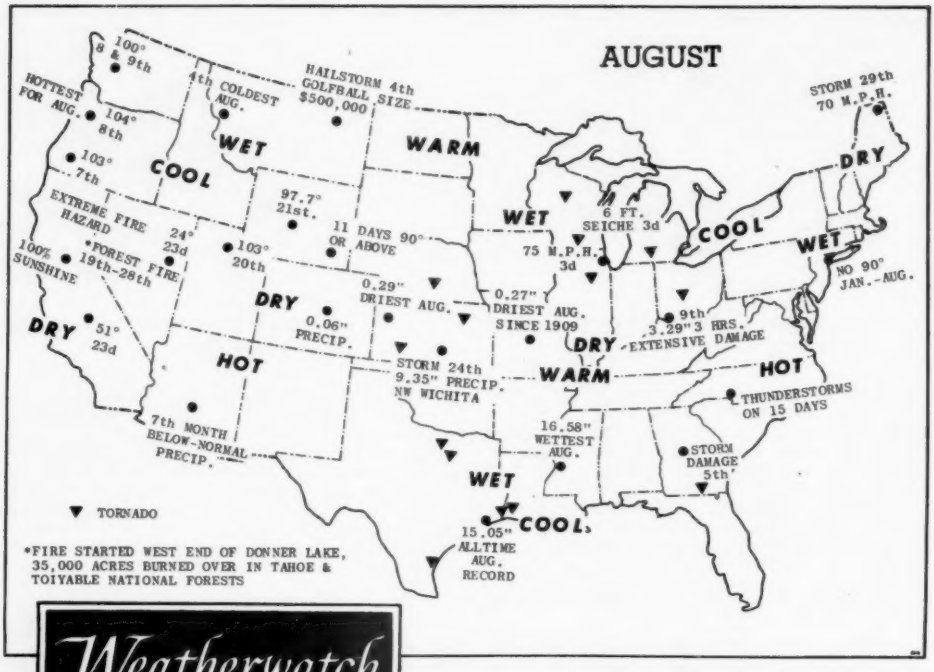
Total Precipitation in inches. USWB chart.

ern Rockies in Montana in two phases: (1) a small high on the 3rd moved southeastward to Missouri by the 5th, and (2) another built up in Montana on the 5th and drifted slowly southeastward to pass off the Carolina coast on the 10th. At that very time another high pushed inland on the Arctic coast of northwestern Canada with a rather high central pressure for summertime: 1033 mb/30.51". This vigorous air mass maintained a steady southward course to enter the United States over Minnesota early on the 14th with a pressure close to 1030 mb/30.42". A continued southeastward movement took it off the Delaware coast on the 16th with pressure now reduced to 1023 mb/30.21". With the intensification of the western ridge over the Plateau which followed in the second half of July, anticyclones tended to move directly eastward over the Great Lakes and through or just north of New England, a track which brought more unmodified polar air into the Midwest and the Northeast. But the Southeast failed to share in these northern outpourings; during the entire month not a single high moved south

(*Continued on page 223*)

The upper-air map below shows the pattern of air flow for July at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.





Weatherwatch

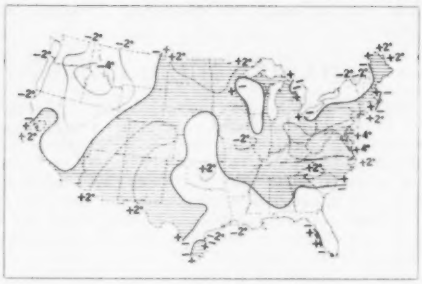
Data by Office of Climatology, USWB.

AUGUST—Dr. Anomaly had little to sate his appetite for weather extremes in the month under study. For most parts of the country it was an uneventful month such as: "Weatherwise, in the Chicagoland area, August was only slightly active." West Palm Beach: "A pleasant month with no weather extremes." Montgomery, Ala: "No unusual phenomena occurred during the month." Philadelphia: "August 1960 was a pleasant month for the most part with nearly normal temperatures." Burlington, Iowa: "August was a very pleasant month; near normal in temperature and drier than usual, but extremely sunny with no very warm or very cold days." Williston, N. D: "This was a very pleasant month . . . no severe storms were reported in this area." Topeka, Kan: "About average August weather-wise." Anchorage, Alaska: "All elements were near normal for the month." It appears that only in the Plateau States and the Northwest where the last half of the month was very cold, and in the lower Mississippi Valley where August was very wet, did the "departure-from-normal" statisticians have much to talk about.

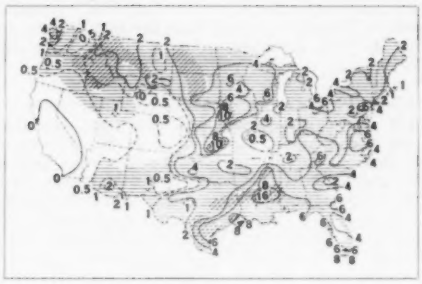
THE WEST—The passage of BRENDA up the East Coast on 30 July provided the outward manifestations of hemisphere-wide changes that were taking place in the distribution of the main pressure systems across the continent as the month of August opened. The most important migration took the eastern Pacific Ocean trough (along 150° W in July) eastward to a position astride the immediate Pacific Coast (125° W). Though there would be a temporary resurgence of the great Plateau high of July at the end of the first week, after mid-August trough conditions would prevail over all areas west of the Rocky Mountains. Record-breaking minimum August readings now took over from the record-breaking highs of July.

As August opened, the Plateau high retreated southeastward to New Mexico as the first of a series of troughs (this one relatively weak) moved into the Northwest from the cyclonic area in the Gulf of Alaska. This gave a check to the extremely high readings of July and brought the mercury down to normal levels. By the 7th, however, the continental high reasserted itself in the form of a strong ridge extending from California to the Carolinas, and another scorching session of tropical continental air settled over the Plateau and Pacific States. Seattle set new date max. records on the 7th, 8th, and 9th (88°, 97°, 97°)—Salt Lake City Airport reached 98° or more on every day from the 7th through 14th.

A second, much more vigorous trough developed in the Gulf of Alaska on 11 August, hovered near the British Columbia coast on the 12–14th, and then commenced a slow transcontinental journey that was to bring important mid-August changes to the weather of the entire nation, to neatly divide the month into two climatological compartments. Temperatures moderated everywhere with the slow passage of this trough eastward. At Seattle on only



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

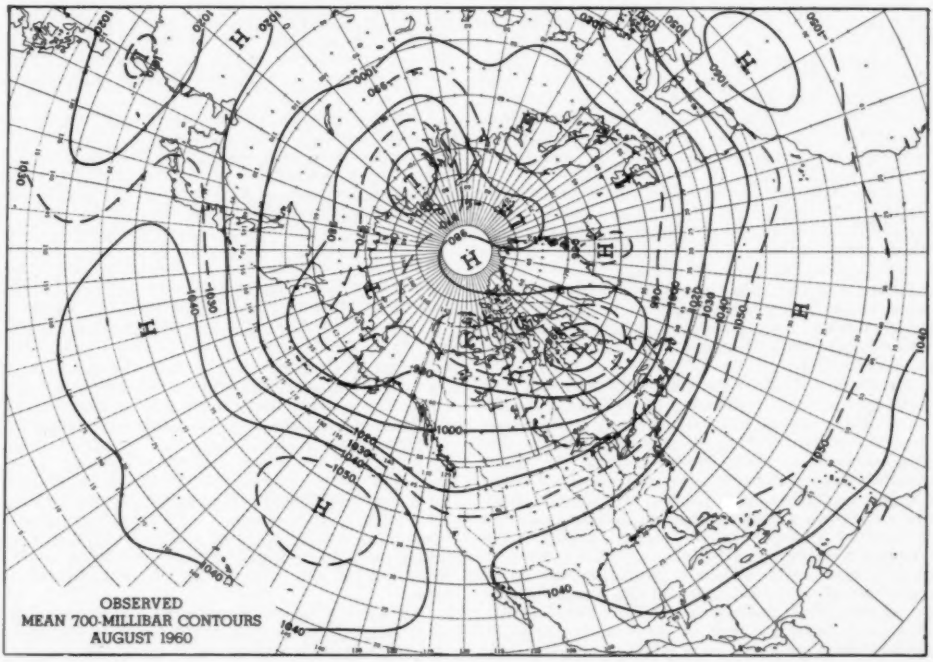


Total Precipitation in inches. USWB chart.

two days after the 9th did the thermometer average above normal readings as a cloudy and showery period set in to bring an early end to the fine Northwestern summer. The highest daily max. after the 9th reached only 74°, a full 23 degrees below the record 97° on the last day of the heat wave.

A third and still more energetic trough pushed inland on the 21st accompanied by an active surface cold front. A strong northwesterly flow brought in a fresh polar Pacific air mass with quantities of chill air. Back from the coastline record low readings for any August were established at many mountain and Plateau locations: Ely, Nevada, turned in 24° and Reno had its first below-freezing reading in any August with 30° on the 23rd. This trough, unlike its predecessors, did not move directly eastward but remained over the Western States as an important feature to continue the cool regime there through the end of the month.

MIDWEST—The great valley areas of the midsection of the country reflected almost immediately the above mentioned changes in the air flow taking place over the eastern reaches of the Pacific Ocean. The first two weeks of August produced a varying weather regime in the Mississippi Valley as minor fronts slipped down out of Canada to bring frequent shifts in air flow and changes in air masses. At Chicago temperatures were above normal on 1–3 August, below on 4–5, above on 5–9, and below on 10–16 August—then a definite warming trend set in and developed into the summer's major heat wave as the month drew to a close. With the reestablishment of the western trough and the building of the Bermuda



high, air flow over the interior valleys and Lakes region came out of the west and southwest. Temperatures at Chicago mounted into the high 80s on the 25th to reach a climax on the 31st with a searing 96°.

EAST—From the Lower Lakes eastward to the Atlantic Coast August weather conditions resembled those of July more closely than in the Midwest or Far West. The low pressure complex over Hudson Bay and northern Quebec continued to be the dominate factor for Eastern weather. Again it was the scene of great cyclonic activity as frontal zones spun southeastward and eastward around this center, pushing polar air at frequent intervals into the Northeast with welcome changes of air mass every few days. The temperature departure figures showed no consistent trend except that unusually high maxima were absent. Not until the 27th, when an authentic Bermuda high situation finally built up, did the Middle Atlantic States and New England have any semblance of a heat wave. Then the mercury generally cracked 90 degrees over all the area. It is interesting to note that much was made in the press that New York City's principal weather station at the Battery (thermometers at a 414′ elevation, open to sea breezes) failed to reach a 90° mark so far this season—89° on the 28th was the peak. All other stations in the Metropolitan area reached 90 degrees several times during the summer—Newark Airport only 6 miles to the southwest had four consecutive 90°-plus days on the 27–30th.

THE SOUTH—July had presented a varied weather pattern in the Southland: hot and dry in the Middle Gulf and very wet and near normal temperaturewise in the South Atlantic. For most of July the area lay in the southern end of the East Coast trough where conditions might be expected to vary from day to day and from one area to another nearby.

August brought more stable conditions. Along with the rest of the country, the temperature and precipitation periods divided into two portions. During the first 15 days, with no active fronts penetrating to the Gulf of Mexico, the reign of heat and humidity continued unbroken until the 16th when a high pressure cell over the Northeast forced a northerly flow of cool, refreshing air all the way to Florida. At Charleston, S. C., where your editor happened to be that day, the temperature ranged from 83° to 65° for a very pleasant day. Thereafter, flux was the theme of the air currents. A re-established southwesterly flow on the 20th gave way to a strong northwesterly current on the 23–24th when a front again penetrated to South Carolina, affording another pleasant day for Palmettoes on the 25th (82°–70°).

On the final days of the month the Bermuda high built up to full summertime strength; along with most of the eastern part of the country, the South returned on the 27th to the 90-degree regime. For the month as a whole, temperatures in the Upper South averaged close to normal, while Gulf Coast sections ran below. Precipitation was light to moderate except in a broad strip from Texas to northern Mississippi where it was very heavy. Probably the greatest weather anomaly for the entire country in August occurred at Vicksburg, Mississippi, where the total rainfall of 16.58″ provided the wettest August of record and the wettest month since October 1918. A new 30-minute record of 2.44″ and a new 60-minute mark of 3.44″ were set there on the early morning of the 22nd in a non-frontal downpour which covered much of Mississippi, Arkansas, and Tennessee.

CANADIAN HIGHLIGHTS

British Columbia. The month of August throughout British Columbia was marked by a surprisingly sharp change in weather regimes. Early heat and drought in July and the first two weeks of August had produced what may be the costliest forest fire season on record. However, beginning on the 13th of August cool and moist air brought much below normal temperatures and rain which soaked both forest fires and tourists.

Over the month as a whole, British Columbia was a little cooler than normal. However several stations reported maximum temperatures of 102° and all-time high temperature records were broken at many stations on or near the coast in the western part of the province. At Vancouver Airport, where temperatures have been observed for 24 years, a maximum temperature of 92° on August 9th was 5 degrees higher than the highest temperature ever reported before in any month.

Normally, coastal areas such as Vancouver do not experience rain of great intensity; however, on August 21st all short period rainfall intensity records were broken at Vancouver when 0.48″ were reported in 30 minutes. Farther inland in the Fraser Valley the town of Hope reported rain on 15 of the last 18 days of the month. The north coastal area and the Lower Fraser valley both had more than twice normal rainfall.

Prairie Provinces. The western part of the Prairie Provinces also experienced a break from warm to cool weather in mid-August. In the eastern Prairies, however, the third week of the month was the warmest. In general temperatures were slightly above normal for August and extremes of more than 90° were common in southern Saskatchewan. The extreme high on the prairies was 98° at Yellowgrass, Sask., while a few stations reported minimum temperatures below 32°.

Early in August, a month-long drought was ended in southeastern Saskatchewan and southwestern Manitoba with a heavy rainstorm that has been described by agriculturalists as a $15 million rain. To the north and east of Winnipeg, an elongated area had the wettest August on record. Gimli reported 7.00″ and Kenora, where records have been kept since 1908, reported 6.70″. On the other hand, an area centered on The Pas in central Manitoba reported only 0.40″, the smallest August rainfall since records began there in 1912. In southern Alberta a tornado struck near Travis Dam on August 3rd, killing one person.

Ontario & Quebec. August was dry in southern Ontario and Quebec with temperatures near normal. Precipitation was above normal only in a band through central Ontario which extended into northern Quebec where Knob Lake had appreciable rain on 26 days of the month. Monthly amounts in excess of 4″ were reported from Knob Lake, Nitchequon, and Fort Chimo, to complete an exceptionally wet summer in that area. In the southern region, however, the Montreal area had only 40% of normal while a small area northwest of Ottawa in Ontario had less than 20% of normal August precipitation.

Latitudinally across Ontario, the average temperature ranged from 71 at Windsor to 55 at Winisk in the north, and departures were usually less than 3

degrees from normal. Maximum temperatures of 92° were reported in the Toronto area while minimums of 32° were experienced at White River, Pagwa, and other locations in northern Ontario. In southern Ontario and Quebec not more than two or three days might have been considered oppressive from the standpoint of humidity and temperature.

The Atlantic Provinces. August brought a continuation of the weather pattern that had become entrenched during the early part of the summer. No low pressure systems passed through the Maritimes although for awhile there was a threat that Hurricane Cleo would move into this district. Cold frontal passages brought the bulk of the month's rain in the form of showers. Bright sunshine totals reached unprecedented August heights in almost all sections and many localities had their driest August in history.

With the high daytime temperatures and extremely low relative humidities forest fires became widespread throughout the three provinces by the end of the month. Farmers were suffering from lack of pasture and from the stunting effect of the drought on late season crops. Urban communities were encountering water shortages and restrictions on the use of water became common by the month's end.

It has been said that the lack of rainfall and abundant sunshine made the month of August in the Atlantic Provinces a vacationer's dream and a farmer's nightmare. Although mean temperatures for the month were everywhere on the warm side, the departures were only one to two degrees above normal. The big story for the month, though, was the lack of rainfall. At such places as Chatham, N. B. (0.40″) and Fredericton (0.57″), the August rainfall was the smallest amount in history. Over the three-month summer period at Halifax, only one summer, 1928, has been drier, and only one summer, 1949, has been sunnier. Bright sunshine records for August were broken at Halifax, Sydney, Chatham, and Fredericton.

The North. Rainfall during August at such locations as Mould Bay (2.50″), Resolute (2.90″), Clyde (4.00″), Cape Dyer (6.50″) and Frobisher Bay (3.50″) was excessive. At Mould Bay, where in 13 years of observations the greatest annual rainfall had been 1.86″, a total of 1.88″ was recorded on August 17th, greatly exceeding all previous daily and monthly values. Measurable snow during the month was reported from Alert and Mould Bay and on August 31st measurable snow on the ground was reported only from Alert (5″).

Temperatures were generally above normal throughout the Arctic islands in August 1960. Eureka and Isachsen both reported average monthly values 5 degrees above normal, while a temperature of 67° was reported as far north as Holman Island. Maximum values in the 80's were experienced at Coppermine and Bathurst Inlet on the mainland. The lowest temperature in the country during August 1960 was 13° at Alert.

HAWAIIAN NOTES

Honolulu. Average temp. 79.2°, or 0.7 degrees above normal. Max. 86°, min. 71°. The rainfall of 0.73″ was 0.36″ below normal.

Hilo, Hawaii. Max. temp. 88°, min. 64°. Rainfall was 12.86″, or 0.94″ above normal. Barometer varied from 30.11″ to 29.92″.

PUERTO RICAN NOTES

San Juan. The temperature of 80.5° was just normal. Max. 90°, min. 71°. Rainfall of 7.65″ was 1.39″ above normal. Fastest mile of wind at airport was 26 mph NE.

ALASKAN NOTES

Anchorage. August weather was near average in all respects. Max. 75°, min. 38°. Highest min. 53°. Prec. 2.70″.

Fairbanks. Fourth successive month with deficient precipitation. 1.71″ was 0.55″ below normal. Max. 82°, min. 35°. Highest min. 51°.

Barrow. The 24-hr. rain of 0.83″ on the 10th was the greatest ever for any such period in August. Average temp. was 34.1°, or 4.3 degrees below normal. Max. 54° on 10th, min. 22° on 21st. Above freezing continuously 5th through 13th.

July (*Continued from page 219*)

of the Tennessee-Carolina latitude to break the hold of heat and humidity on the Southland.

After mid-month the ridge of high pressure in the West developed its own center of circulation over the middle and southern Plateau to institute a very torrid two-week spell in all the West save the coastal strip of Oregon and Washington. Wind flow from the Pacific, moving up the eastern side of the vast trough lying about 1,000 miles offshore, came from the southwest and west-southwest. Interior California experienced one of its hottest July spells in the books, and the whole Plateau area, already in the grips of an unprecedented period of heat, felt the hold of sun and heat intensify till records tumbled right and left. The departures from normal were greater over northern than over southern regions, reversing the June situation when the Mexican border areas surpassed all-time heat marks.

The most important development during the last week of July lay along the East Coast where the upper-air trough intensified and lowered surface pressures close to 982 mb/29.00″ in the seat of action over Hudson Bay. It was through this congenial area of low pressure that BRENDA made its way northward to provide some cyclonic news to a month otherwise dominated by anticyclonic steadiness.

BRENDA—A low pressure area which appeared in the east Gulf of Mexico on 26 July soon developed a rainfall pattern along the west coast of the Florida peninsula. Rain commenced falling at Tampa at 0600/28th and continued until 1700/29th for an amazing total of 13.96″. Of this 12.11″ descended in a 24-hour period to break the previous 24-hour record for any month (10.41″ in June 1945) in observations dating back to 1890. This boosted Tampa's July total to 20.59″, also a record for any month. Lowest pressure at Tampa touched 1006 mb/29.71″ as the low center remained offshore. Heavy 24-hour rains also fell inland at Lakeland (6.61″) and southward at Ft. Myers (3.18″).

After three days of milling around in the northeast Gulf, BRENDA commenced moving north-northeastward on the 28th, crossed northern Florida and extreme southeastern Georgia, and emerged on the coast near Brunswick, Georgia. The center continued just offshore passing Charleston (998.3 mb/

29.48″) at 1330/29th, then again came inshore near Wilmington (995.6 mb/29.40″), and passed 50 miles west of Cape Hatteras (999.6 mb/29.52″) where gusts to 47 mph from SSW were registered late on the 29th.

From Norfolk BRENDA traveled just inland crossing lower Chesapeake and Delaware Bays. Atlantic City registered 993.9 mb/29.35″ as the center dashed northward along the New Jersey coast to make a landfall on Long Island near Idlewild Airport. BRENDA turned on the spigots again here to dump 5.07″ of rain on Mays Landing in south Jersey. The New York City area also received a good doucing as the rain-making process increased:

Newark 2.54″
Manhattan Island (Battery) 4.90″
Manhattan Island (Central Park) 3.56″
LaGuardia Airport (Queens) 3.46″
Idlewild Airport (Queens) 3.46″

The center then moved through New England on the Bridgeport-Hartford-Springfield axis and by midnight rested between Quebec and Caribou, Maine, having traveled 750 miles in 24 hours. Rainfall amounts in Connecticut along the line of progress of the center were in line with those measured in the New York area: Bridgeport 3.57″, Hartford 2.85″. Amounts 100 miles west of the center were also substantial (Albany 2.70″, Pittsfield 1.94″), but to the east falls were generally light—Nantucket 0.17″, Providence 0.72″, Boston 1.00″, Portland 1.54″, increasing as the storm progressed inland and northward. Lowest pressure registered anywhere at a first-class station was 992.2 mb/29.30″ at Bradley Field just northwest of Hartford.

At Mt. Washington winds reached a peak of 92 mph from the ESE for a one-minute period as BRENDA approached from the south and passed nearby. A rainfall of 3.02″ collected at the 6,262′ elevation.

WESTERN HEAT—With the disappearance of a temporary low pressure trough over the Western States on 3–4 July, the Pacific anticyclone reasserted itself in normal summertime fashion and built up well inland over the Great Basin to set the scene for a very hot July. Whereas in June the center of the greatest *much above* temperature departures lay along the Mexican border, now the center of the heat area resided along the Canadian border. From the crest of the Cascade Mountains eastward across Oregon and Washington all the way to the western Dakotas it averaged *much above*.

At Boise, Idaho, it was the hottest July ever, and several points in Montana with 80-year records had their second hottest July. Occasionally the heat bulged over into the northern Plains where Bismarck, North Dakota, saw the mercury soar to 108° on the 20th, the hottest registered there since 1941, and to 105° on the 23rd.

At Boise it was hotter than any other July by 2.4 degrees. A new all-time high of 111° was reached on the 19th. On 27 days the mercury climed to 90° or more to exceed the former record by three days. On 11 days it surpassed 100°, besting the former mark by four days. On every day from the 5th to the 30th (with the single exception of the 24th with a minus departure of one degree) the mercury averaged above normal.

The heat wave also covered eastern Washington where Spokane and Walla Walla had their second hottest Julys, only 1906 exceeded the 1960 figures. Another section of *much above* readings covered most of Utah where Cedar City reached its highest figure in 50 years of record, and at Salt Lake City it topped 107°, the highest ever attained since the commencement of records in 1874. At the latter point the maximum exceeded 100° on eight straight days from the 15th to the 22nd.

Interior California also fried. In the 84-year record at Sacramento only five other Julys were hotter, and the 15-day period from the 14th–27th comprised one of the most scorching ever experienced downtown at the California capital. Through a 9-day stretch, eight days had maxima of 100°. The peak of 111° was reached at the airport on both the 19th and 21st.

Even coastal San Diego, usually cooled by a summer northwesterly flow, had a very hot last-half month when the winds prevailed from the SW and WSW. In July 1960 there were 14 consecutive days with 80° max. or more—since 1875 this duration had been exceeded only two times, and never in July. The 80% possible sunshine was 13% above the average and the highest since a check of this element commenced in 1890.

ALASKAN NOTES

Juneau. July was an unusually cloudy month, with a record-breaking 30 cloudy days and a 9.5 average cloudiness. Lack of sunshine held temperatures down. The max. of 75° was only one degree above the record low max. for July, and the mean max. equaled the record. Rainfall, though frequent, totaled a little less than the normal of 4.65″.

Barrow. Temperature averaged below normal on all days except during two brief heat waves: From 9th to 13th the daily max. was 51°, 68°, 75°, 66°, and 55°; and on 17–18th, 53° and 56°. Lowest daily max. was 34° on 5th and 16th. Absolute min. 28°. Min. below 32° on 23 days. Only a trace of snow fell in the total of 0.21″ precipitation.

PUERTO RICAN NOTES

San Juan. Average temp. of 80.7° was 0.7 degrees above normal. Max. 88°, min. 70°. Rainfall of 4.21″ was 1.81″ below normal. Airport barometer varied from 30.12″ to 29.95″.

HAWAIIAN NOTES

Lihue, Kauai. Warm tradewind weather with slightly less than normal rainfall and more than an average amount of sunshine made July an excellent month for outdoor activities. No extremes were noted. A pendant cloud to the east of the airport occurred shortly before sunset on the 9th. Max. 87°, min. 68°. Rainfall 1.34″.

CANADIAN HIGHLIGHTS

British Columbia. There was frequent Pacific storm activity over the north coast of British Columbia, while the rest of the province had warm sunny weather and less than 25% of normal rainfall. Ethelda Bay on the northwest coast reported 8.4″, the heaviest point precipitation in western Canada, but many stations in the southern part of the province did not record any measurable rain during the month.

Large temperature anomalies occurred in the southern interior valleys where many stations reported monthly means six degrees above normal. Osoyoos with a mean temperature of 77° was the warmest

station in the country for the month, and many stations reported daily maxima in excess of 100°.

Prairie Provinces. On the western Prairies the month's weather has been described as "a perfect month for vacationing." Temperature ranged from normal in Manitoba to five degrees above normal in southern Alberta where several stations reported near record temperatures for the month. At Edmonton, the mean temperature, 66°, equalled that of the warmest month on record, while several dozen stations in southern Saskatchewan and Alberta had monthly extremes exceeding one hundred degrees. The maximum temperature in Canada for July 1960 was 105° at Whitla, Alberta.

July was dry on the prairies especially in Manitoba where it was the driest July on record at several locations. There were, however, storms of short duration giving locally heavy rainfall, hail, and near tornado-like conditions. On July 18 at Neepawa in southern Manitoba, 50 box cars were derailed from a railroad during the passage of a severe thunderstorm. On 19 July, extensive hail damage was reported with hailstones up to 3″ in diameter in the Red Deer area of central Alberta and on 24 July, six inches of precipitation occurred in one storm in the Stoney Mountain area of northeastern Alberta.

Ontario and Quebec. The summer 1960 pattern of cool nights and warm comfortable days continued in southern Ontario and Quebec. Discomfort from heat and humidity was relatively infrequent as 94° was the highest temperature recorded in either province and there were no lengthy periods of hot humid weather.

The trend for excessive rainfall in northeastern Ontario and northwestern Quebec also continued. Several stations in the Lake Temiskaming area reported totals for the three-month period from May through July in excess of 16″ which is an all-time record for these months in that region. Rainfall was below normal in the Ottawa-Montreal area, but at Toronto a severe storm on 9 July left more than 3½″ on a small area in the northwestern suburbs.

Atlantic Provinces. Although there were frequent cold frontal passages with light showers during the month in the Maritime Provinces, the weather was generally sunny and dry, with normal temperatures. As the low pressure areas moved across Quebec well to the north of the Maritimes, only one active low appeared off the Nova Scotia coast until tropical storm BRENDA moved up at the end of the month. Temperatures were remarkably uniform, with very few cold days and no occurrences of temperatures of 90° or over. Southern New Brunswick had more precipitation than normal, while Nova Scotia had slightly less than the usual amount. Most stations in Newfoundland reported less than 50% of normal precipitation.

The North. Isachsen in the far northern Arctic and Resolution Island in Hudson Strait both reported a mean temperature of 38° for the month and were the coldest locations in the country. The extreme low for Canada was 26° reported at both Isachsen and Kleena Kleene in British Columbia. Precipitation amounts averaged an inch throughout the Arctic which was above normal in the west and below normal in the east. Some stations reported as many as 5″ of snowfall during the month, but no station reported snow on the ground on July 31st.

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a new DECCA windfinding radar type WF2

★ **High Performance**—A new high power transmitter increases maximum slant range to well beyond 150,000 metres. A smaller target can be used for normal ranges thus keeping operating costs to a minimum.

★ **Improved instrumentation** making the equipment suitable for one man operation and still further improving the day to day economy of the primary radar windfinding system.

★ **Variable beamwidth aerial** producing a broad beam for picking up the reflector target at the start of an ascent at night in bad weather.

★ **Re-designed operators cabin** with built-in air conditioning and all-round accessibility to electronic units.

Developed from Type WF1 which is in service with some 20 meteorological authorities, the new Decca Windfinding Radar is easy to operate and maintain, and is capable of providing regular, accurate upper wind data at low operating cost.

lower daily operating costs

reflector ranges in excess of 150 km

one man operation

a simple efficient proven system

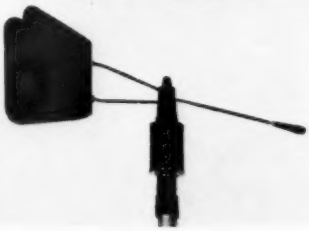
DECCA RADAR

DECCA RADAR LIMITED · LONDON · ENGLAND

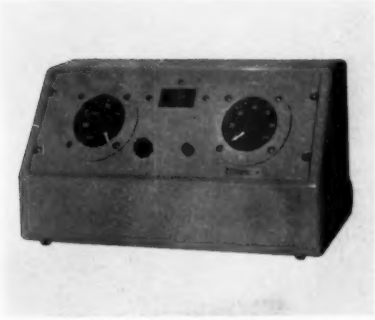
DR 109b

BELFORT TYPE M WIND SET

This is the same wind vane and housing as used in instruments built by BELFORT for FAA and the Weather Bureau.

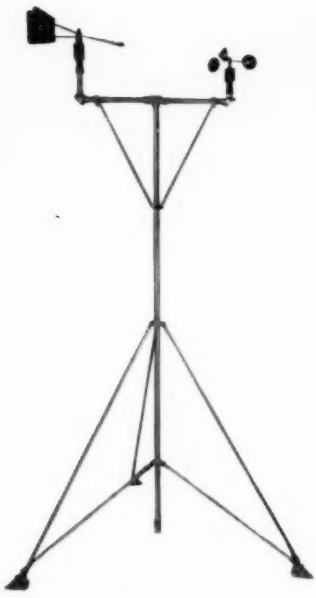


This three cup design is supplied for Weather Bureau and FAA installations.

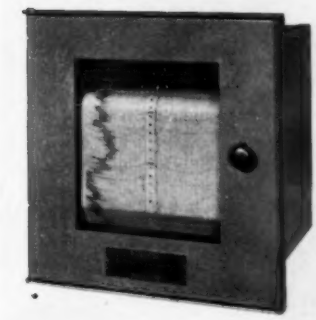


Indicators identical with standard Air Force models built by BELFORT.

Similar indicators mounted for relay rack.



Transmitters with support

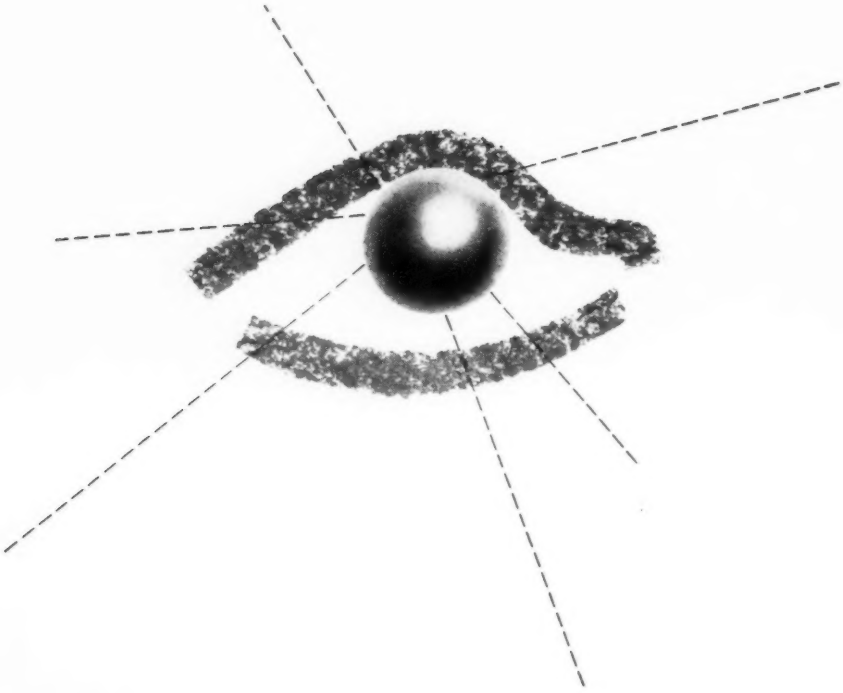


Patented mechanism produces direction record running from 0° to 360°. Each compass point appears only once. No other recorder offers this simple interpretation.

Same recorder with weather proof case.

Send for our new catalogue.

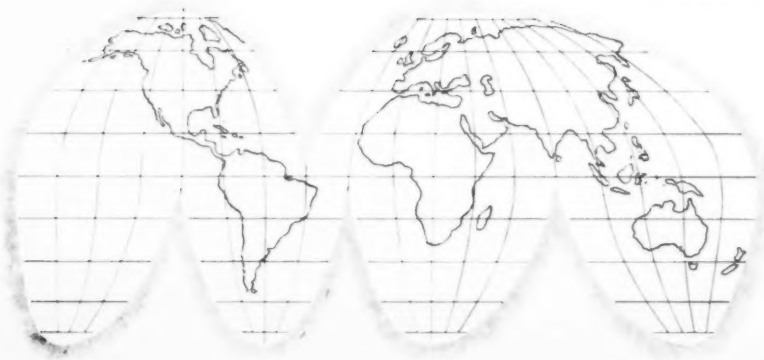
BELFORT INSTRUMENT CO.
4 N. CENTRAL AVE.
Baltimore 2, Maryland



eye in the sky...

Air currents can be "seen" with DAREX radar reflector balloons. Accurate radar tracking is ensured by aluminum reflective dipoles safely *inside* the light, strong, one-piece DAREX skin. If your weather eye looks for dependability and economy in balloons, look to us.

W.R. **GRACE** & CO.
DEWEY AND ALMY CHEMICAL DIVISION
Cambridge 40, Mass.—Montreal, Quebec

DAREX ***better balloons***

...since 1935, leading makers of captive balloons, ceiling balloons, pilot balloons, kite balloons, sounding balloons, radar reflective balloons, constant level balloons, inflation kits.